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ENERGY DEMAND AND RESOURCES OF JAPAN. VOLUME II

K. Dance, et al

Science Applications, Incorporated

Prepared for:

Rome Air Development Center
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August 1973

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The objective of this study was to prepare projections of Japanese energy demands through the year 2000, and to identify potential sources of conflict which might arise as Japan attempts to secure her needed energy supplies. In addition, potential areas of technology transfer to Japan which could have a stabilizing influence on the world energy situation are identified.

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HYDROELECTRIC POWER

A.1 Historical Summary

Hydroelectric power was the force that started Japan on its course from a feudal society and economy, only a century ago, to a modernized industrial society. Once the prime energy source for industrial transportation and commercial development, hydroelectric energy has dropped from supplying approximately 80 percent of the national power requirements in 1945 to less than 25 percent in 1973. Hydroelectric development however continues to expand, but at a far less spectacular rate than competing forms of electric power, primarily thermal. Only nuclear power is developing at a slower rate, but within the next few decades we expect to see this energy source pass hydroelectric power as new large plants come online.

A.1.1 Background

Modern, industrial Japan began to emerge, not with the celebrated Perry visit of 1858, but with the Meiji Restoration of 1868. At that time, Japan was all but "ready" to enter the industrial age, and had essentially outgrown the feudal system that had existed for the previous three millenia. Perry provided a catalyst to a process already incipient, but the Emperor Meiji was the primary driving force behind Japan's spectacular move into an industrialized society. Meiji, having overthrown the Tokugawa Shogunate, moved the capital from Imperial Kyoto to commercial Edo (Tokyo) and was highly receptive to inputs from all the industrialized nations of the world that might help his country catch up with a thousand years of technological isolation. England and the United States were the prime forces in "Japan's Industrial Revolution," and dispatched technical missions not dissimilar to those sent to developing nations today. With respect to electric power, this "dual sponsorship" had one unfortunate result. English engineers were active in the planning and development of the first metropolitan and regional systems in the Kwanto (Tokyo and environs) Plain, and introduced the British equipment and 50 cycle service. In Kansai (Kyoto-Osaka-Kobe and environs), American electrical engineers, aided in establishing 60 cycle service. This difference has caused considerable economic and technical problems, primarily in the establishment of a nation-wide power transfer grid, and consequently in the capability of transferring the output from a power-surplus region to an area of power shortages. This incompatibility impacted severely upon early industrialization of Japan and led to a large number of "captive" hydroelectric plants being constructed by industry and later by the Japan National Railways, as they began their electrification process. The 50/60 cycle zones still impede a truly national grid, but have been partially linked by an elaborate frequency conversion station at Sakuma in which 500,000 (vDC) is used as the conversion vector. However, in normal usage, Honshu is divided in the Nagoya area, with 50 cycle service being used in the north, including Tokyo and extending to Hokkaido, and 60 cycle service used in the south, including the islands of Shikoku and Kyushu. The Sakuma conversion station is used as a loading dispatch facility, and not as a primary link for sustained periods of time. *

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* One advantage of 50/60 cycle pattern in Japan has been the manufacture of dual-cycle electrical equipment for domestic use and subsequently for foreign consumption. Particularly in the area of small appliances, the 50/60 cycle feature makes them equally attractive to U.S. and European markets.

In implementing hydroelectric projects initiated either immediately prior to or during World War II, Japan demonstrated a high level of competence in the development of advanced technology hydroelectric systems on the Home Islands (primarily Honshu), Taiwan (the Sun-moon Lake Project), and particularly in Korea. The geography of North Korea was particularly well suited for en-echelon hydroelectric plants, and the Japanese engineers showed great technical skill in extracting the last component of energy from falling water in a series of massive developments, the best known of which is the Changjin (Choshinko) system, site of the infamous US Marine "Chosin" Reservoir Campaign" in the winter of 1951. Similar geography prevails on the west coast of Japan, where water from the mountains is conducted through tunnels into reservoirs, dropped many hundreds of feet into high-energy Pelton turbines, thence, with greater volume into two or more conventional Francis turbines downstream, and finally through an aqueduct to a run-of-river plant using either Francis or Kaplan (propeller) turbines. In such areas, by the time it reaches sea level, one cubic meter of water typically passes through three and sometimes as many as five hydroelectric plants.

Sites with such favorable geography are almost exhausted however, and, particularly in older installations, there has been appreciable silting associated with the 30 or more serious typhoons that have swept the watersheds of these plants. However, until large-scale thermal plants were constructed, primarily on the east and southern coasts of Japan, these large-scale hydroelectric developments provided the mainstay of Japan's industrial development. Hydroelectric power is still a significant element of Japan's electric power base.

A.1.2 Physical Geographic Factors

Japan has a monsoonal climate, with most of the precipitation occurring in the spring and late summer months, during the onset of the moisture-laden southwest monsoon. Frequent typhoons in the summer and fall also contribute to the hydrologic budget of the country, and, as a rule, floods are far more common than droughts. The Japan Sea Coast and Hokkaido are affected by the climate of Siberia during the winter months when dry cold air traverses the Sea of Japan from the North Asian Mainland and acquires considerable moisture in the process. Upon encountering the mountainous Japanese Archipelego, much of this moisture falls as snow, particularly in the mountainous areas of central Japan, known as the Japan Alps and site of many of the major hydroelectric developments of Honshu. The central mountains also contain the headwaters of the rivers that supply more than half of the national hydroelectric capacity. The spring "rainy season" is caused by a stationary polar front which brings heavy rains to the entire country and often cannot be contained by the catchments already full from the spring thaw. The "hydroelectric inventory" is used throughout the typically dry summer until replenished by intermittent tropical depressions or typhoons that again overload the catchment capabilities. The limited reservoirs result in often too little hydroelectric reserves during the winter months. Floods are a continuing problem and the trend therefore has been away from the original "minimal capacity" dams to larger storage and flood control dams, less dependent upon variations in the climate. The dams have become larger and more complex; the hydroelectric heads higher; and the generation capacities greater.

With one exception, the new large facilities either under construction, planned, or being expanded are of the pumped storage type. Pumped storage, discussed in greater detail below, obtains maximum efficiency from such high-capacity installations.[1]

A.2 Status of Hydroelectric Power in Japan

A.2.1 General Employment

Hydroelectric power in Japan, a primary source of energy in the pre-World War II days and a major contributor to Japan's Industrial Renaissance in the 1950s, has become a supplemental power source in the 1970s (Figure A.1). By the early 1980s, less than 4 percent of Japan's energy requirements will be satisfied by this energy source. Geography has been the basic limiting factor. Although hydroelectric power sources will continue to be developed, albeit at a considerably slower pace than the development of alternative sources of energy, limitations in such things as dam and power plant siting, environmental impact, and possible seismic interactions (including the hypothesis that some minor seismic activities have been generated by hydroelectric water impoundments in seismically-unstable areas) have limited the future development of Japan's onetime primary energy source.

New hydroelectric facilities will be established; old facilities will be modernized and upgraded; and it is doubtful that any of Japan's installed hydroelectric capacity will be abandoned. But competing energy sources, primarily oil-fueled thermal plants will continue to assume an increasingly significant share of the electrical energy demands of Japan (until overtaken by nuclear plants). The basic reason for this development is primarily the increased efficiency of contemporary large-capacity thermal power plants – an efficiency that cannot be matched even by the most sophisticated hydroelectric developments. The use of multi-purpose irrigation and power installations, and the advent of pump storage systems have kept hydroelectric systems a competitive and essential element of the overall national power system, but they no longer dominate the system.

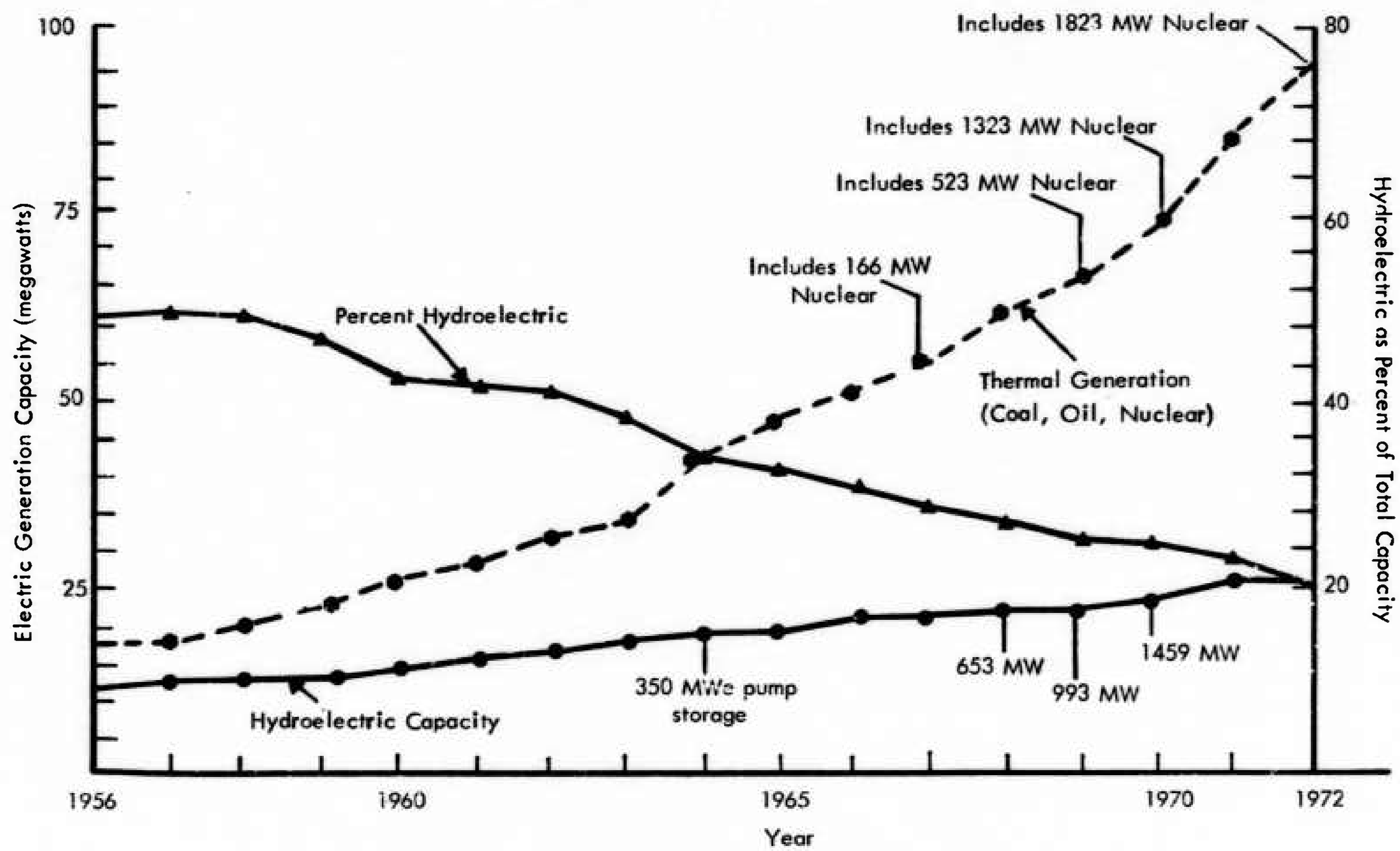

Figure A.1. Development of Electrical Power Generating Capacities of Jcpan(2)

The current position of the Japanese electric power industry is "thermal primary and hydro secondary." Hydroelectric generation will be sustained to carry peak loads, particularly in summer. Since the introduction of nuclear power (the first plant went on line in 1967), thermal and nuclear have been used to carry the primary demand loads and will be supplemented by new, sophisticated, but still supplemental, hydroelectric developments.

A.2.2 Hydroelectric Power — 1972[2]

Hydroelectric power generation has lessened in overall significance in the context of the total power generation capabilities of Japan, but is still a very significant part of Japan's present and projected energy resources. In March 1971 hydroelectric power represented 26 percent of Japan's installed generation assets and was responsible for 22 percent of the annual electric power generation for 1971. Much of this use, which will be continued, was in the assumption of the "peak load" function described earlier. From an examination of Figure A.1 and other figures in this appendix, it might be inferred that hydroelectric power is almost insignificant and in the process of being phased out in favor of thermal and nuclear generation. On the contrary, hydroelectric power still represents an expanding energy asset of Japan; it is however expanding at a much slower growth rate than thermal plants. Its growth rate, however, exceeds that of nuclear plants, and only towards the end of the present decade is nuclear power expected to surpass hydroelectric generation.[1]

In the past decade for example, a total of 9790 MW of new hydroelectric generation capacity was added, representing approximately 20 percent of the nearly 50,000 MW of generating capacity added nationally. Nuclear plants began to come online in 1967 and by 1970 represented 2.6 percent of the national capacity.[2]

Figure A. 2 presents the new construction in power plants of various categories together with the percentage of the power coming online that year from the various sources. The extreme annual fluctuations represent large-capacity units coming online at various points in the decade, considerably altering the overall proportion of new construction completed (or partially completed with one component or more being placed online) in any given year. Possibly a more general overview of the significance of hydroelectric power in the overall Japanese energy context is shown in Figure A.3 in which the annual energy production for the same period is shown in megawatt hours, based upon hydroelectric and thermal plants contributing to the national energy grid. * Figure A. 3 incorporating both new construction and hydroelectric plants fifty years old or more shows that hydroelectricity still makes a substantial contribution to Japan's energy demands.

By the end of March 1972 there were nearly 1,600 hydroelectric power plants operational in Japan. Most were small, run-of-river or mountain units taking advantage of selected areas in which an exploitable hydroelectric site could be established at remote mountain areas. New construction has turned from the small local installations to large-scale units in excess of 100 MW capacity.

With one exception, all hydroelectric construction planned to 1980 will be of the pumped storage type, in keeping with the role of hydroelectric power as a peak load buffer capacity. There are only 25 plants in operation with capacities in excess of 100 MW; nine between 100 MW and 500 MW; and one in excess of 500 MW. Fifteen

* Three of the four Japanese Home Islands are interconnected in a national power distribution grid that will be extended to Hokkaido in 1977. The Sakuma frequency-conversion station makes the interconnection between 50/60 cycle zones feasible.

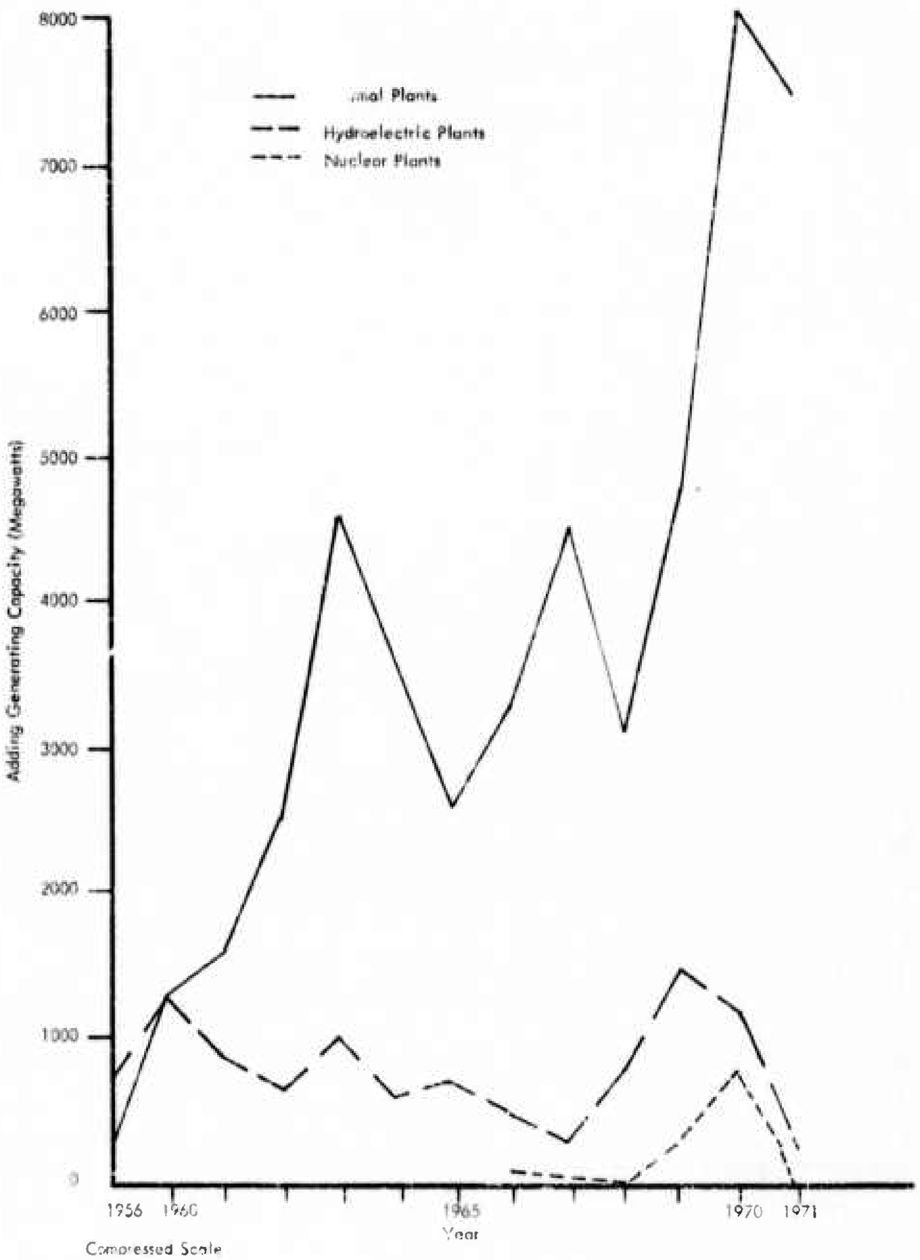

Figure A.2. New Electric Power Plant Construction, 1960–1971 (megawatts added per year and percent of total power plant construction per year by category of energy source)

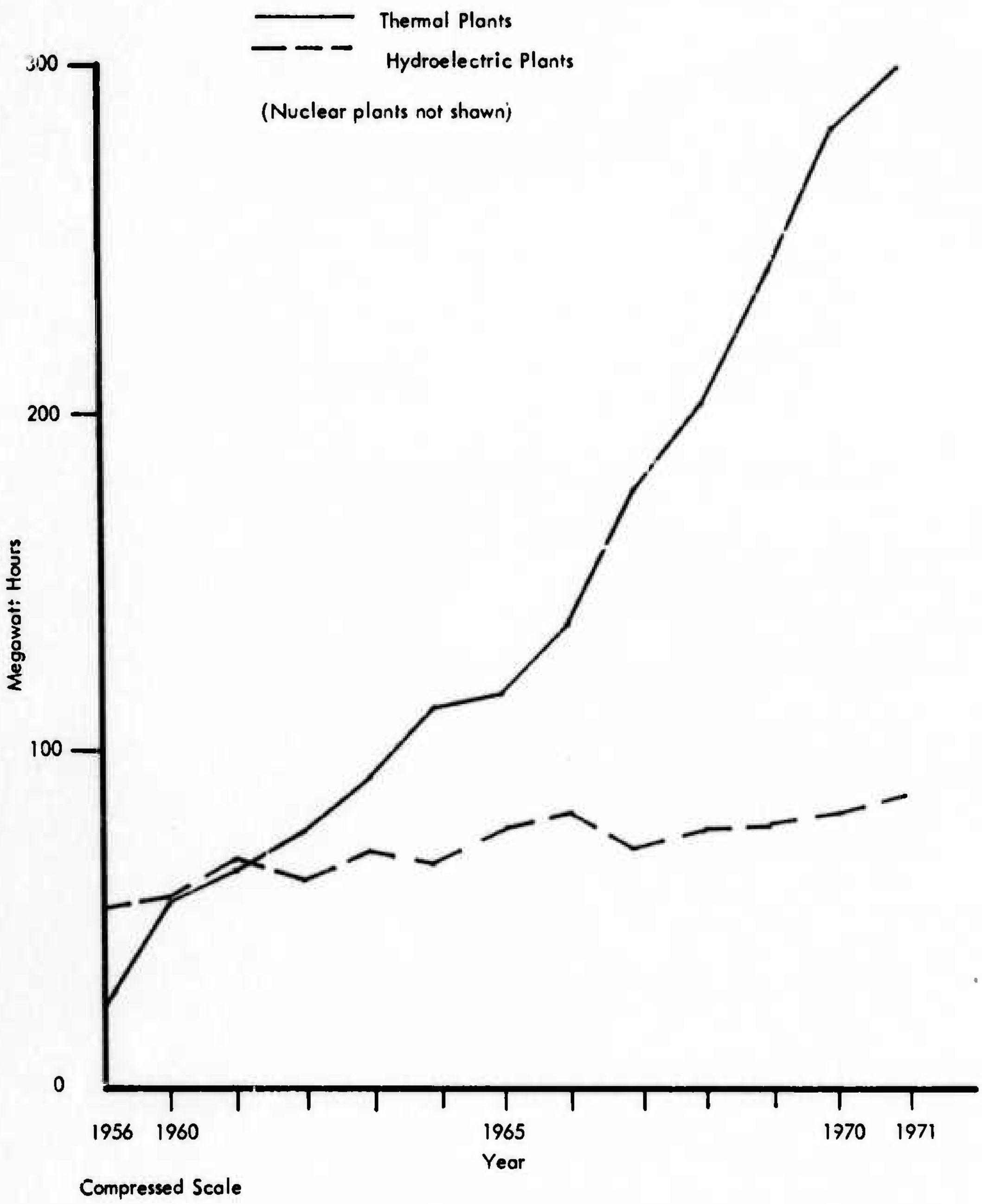

Figure A.3. Electrical Energy Consumption by Energy Source, 1960-1971 of these 25 are conventional storage and run-of-river plants. Most of these units are elements of multipurpose dams and reservoir systems in which electric power generation is secondary to flood control and irrigation requirements. With the exception of the Kurbuegawa #4 plant, a 258 MW installation using vertical Pelton turbines, all new construction and the bulk of the larger units (100 MW and above) use Francis Turbines in areas of high to moderate head, and Kaplan turbines at sites of high volume and low head.

Plans call for the construction of two plants in the 200-300 MW range, four plants in excess of 500 MW and four plants in excess of 1,000 MW.[2] These new units will be of the pumped storage type. With a daily drawdown at the dam of 20 or 30 meters which exposes shore-lines in an unesthetic fashion, the pumped storage plant has begun to come under the attack by environmentally oriented groups of the Japan population — as has been the case in the U.S.[3] The storage-only type of hydroelectric installation may achieve a moderate renaissance at some sites, particularly those in the Japan Alps National Park.[3]

The MITI policy is of primary dependence upon thermal, and eventually nuclear power, with hydroelectric installations serving as peak period buffer capacity; this policy combined with requirements for flood control and irrigation have directed almost all new hydro-electric installations in Japan to be dual-purpose pumped storage systems. Only one new "storage only" hydroelectric installation is planned for the next decade in the "large" (100 MW or larger) size hydroelectric systems.

Japan built, as long ago as 1943, some of the world's most advanced pumped storage systems in Korea. However, the geography of North Korea permitted the construction of large reservoirs "en echelon" on the high rolling plateaus and required only a small investment in pumping equipment to refill the primary storage reservoirs for their massive hydroelectric developments. Reversible pump turbines, a later development, were not used at these installations. Some of the planned pump storage systems may not be built, for environmental pressures are building up in Japan, as in the US, opposing the esthetics of appearance of a large, essentially empty, pumped storage reservoir whose level may have dropped as much as 100 feet in midsummer which leaves an exposed shoreline consisting primarily of mud and dead vegetation. Both recreational and irrigation aspects of pumped storage reservoirs are minimal, and there is a small ground-swell of opinion that the construction of several installations, particularly in scenic areas such as the Chubu Samyaku National Park, be halted. (A similar project was recently halted, as the result of environmental pressure, in Thailand's Kao Yai National Park, so the possibility of such events cannot be overlooked.)[4]

Present plans for pumped storage hydroelectric installations in Japan are shown in Table A.1. Unless otherwise indicated, all are located on the main island of Honshu.

A.3 Future Prospects of Hydroelectric Power in Japan

A.3.1 Projections of Hydroelectric Construction

Hydroelectric power has a significant place in future energy forecasts for Japan, since it is a dedicated system, representing an extensive inventory of equipment, and is essentially a non-transferable energy asset - i.e., it produces only one product (electric power) and does not compete with other energy sources for use in non-energy areas (e.g., oil for petrochemicals). In this respect, hydroelectric power is parallel to nuclear power.

Table A.1. Pumped Storage Plants of Japan (250 MW and larger)

Name	Installed Capacity MW (Interim)	Effective Head (m)	Commissioned (expected completion)**
Ikehara	(160)	120.5	1964
	350		1966
Azumi	(222)	135.7	1969
	436		1970
Kisen-yama	466	220	1971
SUBTOTAL (1971)	1,252		
Shin-toyone	1,125	203	(1972-73)*
Okutataragi	1,212	383.4	(1974-76)*
Nabara	620	294	(1975)
Ohira (Kyushu)	500	489.7	(1975)
Masegawa #1	286	100.5	(1974)
Oku-yoshino	603	506.5	(1976-77)*
Shin-tasegawa	1,280	229	(1977-78)*
Numappara	675	478	(1977-78)*
Oku-kiyotsu	1,000	469.75	(1978)
SUBTOTAL OF PLANTS U/C	7,301		
TOTAL PUMPED STORAGE CAPACITY AVAILABLE BY 1978	8,553		

* Partial capacity (e.g., one or more turbogenerator sets online) by first date; full production available on second date.

**Head indicates required horsepower to operate reversible turbines in pump mode. Horsepower to be drawn from thermal capacity or nuclear capacity in post-1980 period during non-peak hours. Rate of fill as a function of horsepower requirements not available, in direct form, but by 1985 between 272 and 300 MW are estimated to be required as demands on the energy supply to furnish pumping capabilities for the off-peak refill of pumped storage facilities.

Source: Reference 1

Official forecasts (which have varied markedly since 1968) have been made by the Ministry of International Trade and Industry (MITI)[2] and by various groups in the private sector. MITI predicts that hydroelectric capacity will increase 17.3 percent between 1975 and 1985, with almost 70 percent of this increase occuring in the 1975-1980 period. The Institute for Energy Economics (IEE)[5] has a more optimistic forecast that strangely inverts the timing and predicts a 40.8 percent increase in hydroelectric capacity over the same period, with approximately 75 percent of the increase predicted for the 1980-1985 period. IEE obviously believes that new sites will be found and that the drive for additional non-polluting energy will cause what amounts to a renaissance in hydroelectric development.

The IEE position is shared by Prime Minister Tanaka who, in his new book "Building a New Japan,"[6] makes a strong case for multipurpose dams primarily for flood control and domestic water supply. Such impoundments, while not as efficient as hydroelectric systems built solely for power generation, would provide a massive potential for future hydroelectric development. The problems of adequate irrigation and municipal drought are very real in Japan (there have been several severe water shortages in the past decades), so the Prime Minister's point is well taken. However, his ambitious plan for virtual reconstruction of Japan and massive relocation of existing transportation, industrial, supply, and distribution systems is highly controversial; it may not be implemented in its proposed form without serious political perturbations.

Under construction at the present time (1972 data) are 7301 MW of pumped storage hydroelectric plants, the last of which is expected to be online in 1978. In the period 1964-1972, 3430 MW of hydroelectric power of both pumped storage and standard storage types were established. This continuing construction essentially represents the final "wave" of hydroelectric development in Japan, as suitable sites for large-scale developments, (and generally 250 MW is considered the "floor" for construction of contemporary hydroelectric plants) become more and more scarce. Thus by 1978 the approximately 11,000 MW of new construction will represent the last major hydroelectric investment by Japan for the foreseeable future.

Table A.2 shows how hydroelectric power assumes an increasingly minor role in the context of the total energy requirements of Japan.

Table A.2. Historical and Forecast Contributions of Hydroelectric Power to the Electric Power Energy Resources of Japan

Year	Total Energy Supply (10^{12} kilocalories/yr)	Hydroelectric Energy Supply (10^{12} kilocalories/yr)	Hydroelectric as Percent of Total
1960	937	143	15.3
1970	3,105	196	6.3
1975	4,300	213	5.0
1980	6,250	235	3.8
1985	8,500	250	2.9

A.3.2 Peak Power Requirements Role of the Hydroelectric Power Industry

Within the past decade, the electric power industry has decided to place prime reliance upon thermal power (with an eventual shift to nuclear power in the latter years of the century) and to use hydroelectric power to handle peak load periods. Such peaks typically come in the summer months as shown in Table A .3 and Figure A .4. It may be noted that even in 1985 approximately 20 percent of the peak season power demand will be taken on by hydroelectric power stations, primarily those of the pumped storage type, described on the following pages. Figure A. 4, adapted from the document "Problems of Energy in Japan"(2) (in Japanese) and published by the Ministry of International Trade and Industry, portrays electrical power usage during a "typical" August day of 1985. Note that during the night hours, energy from online nuclear and thermal systems supply energy to fill the storage reservoirs of the hydroelectric pumped storage systems. Commercial, industrial, and (by 1985) residential air-conditioning requirements cause the greatest demand to occur in the early afternoon. MITI estimates that in a "peak demand day" in August 1985, between 272×10^5 MWhr and 313×10^5 MWhr will be required to fill the massive pumped storage installations either under construction or planned for Japan at that time. The concept of use of energy to create energy reserves can only be accomplished by well-established off-peak excess capacity. The required off-peak capacity, as shown in Table A .3, can be provided by run-of-river hydroelectric plants that will be online at all times; nuclear plants that will operate continuously; and some thermal units, particularly large generators and turbines that have long start-up and shut-down periods.

A. 3. 3 Summary and Conclusions

Hydroelectric power will continue to maintain a significant role in the overall energy resources of Japan. As shown in Table A .4, the percentage of the national energy, and specifically the national electrical energy supply contributed by hydroelectric power declines and is forecast to decline dramatically throughout the next decade.

Table A.3. Normal and Peak Requirements for Electric Power in Japan

Energy Source	1970		1975		1985	
	Normal (MWhr x 10^5)	Peak (MWhr x 10)	Normal (MWhr x 10^5)	Peak (MWhr x 10)	Normal (MWhr x 10^5)	Peak (MWhr x 10)
Hydroelectric	758	1,546	805	1,980	947-976*	4,102-4,504*
Thermal	2,141	3,389	3,658	6,779	6,207-7,239*	10,960-12,569*
Nuclear	35	35	400	458	3,910	
Local Power	12	22	9	10	9	10
Power used for pump starage in nan-peak periods (-)	(-) 41		(-) 50		(-)272-(-)313	
Peak Demand (EST)		4,837		8,394		18,656-20,483*
Peak Supply		4,992		9,227		20,522-22,531
August Power Reserve		155		833		1,866-2,048
%Estimated Reserve		3.2		9.9		10.0
% Demand Carried by Hydro		32.0		23.6		22.0-21.9

* GNP growth estimated at 9.5% per annum.

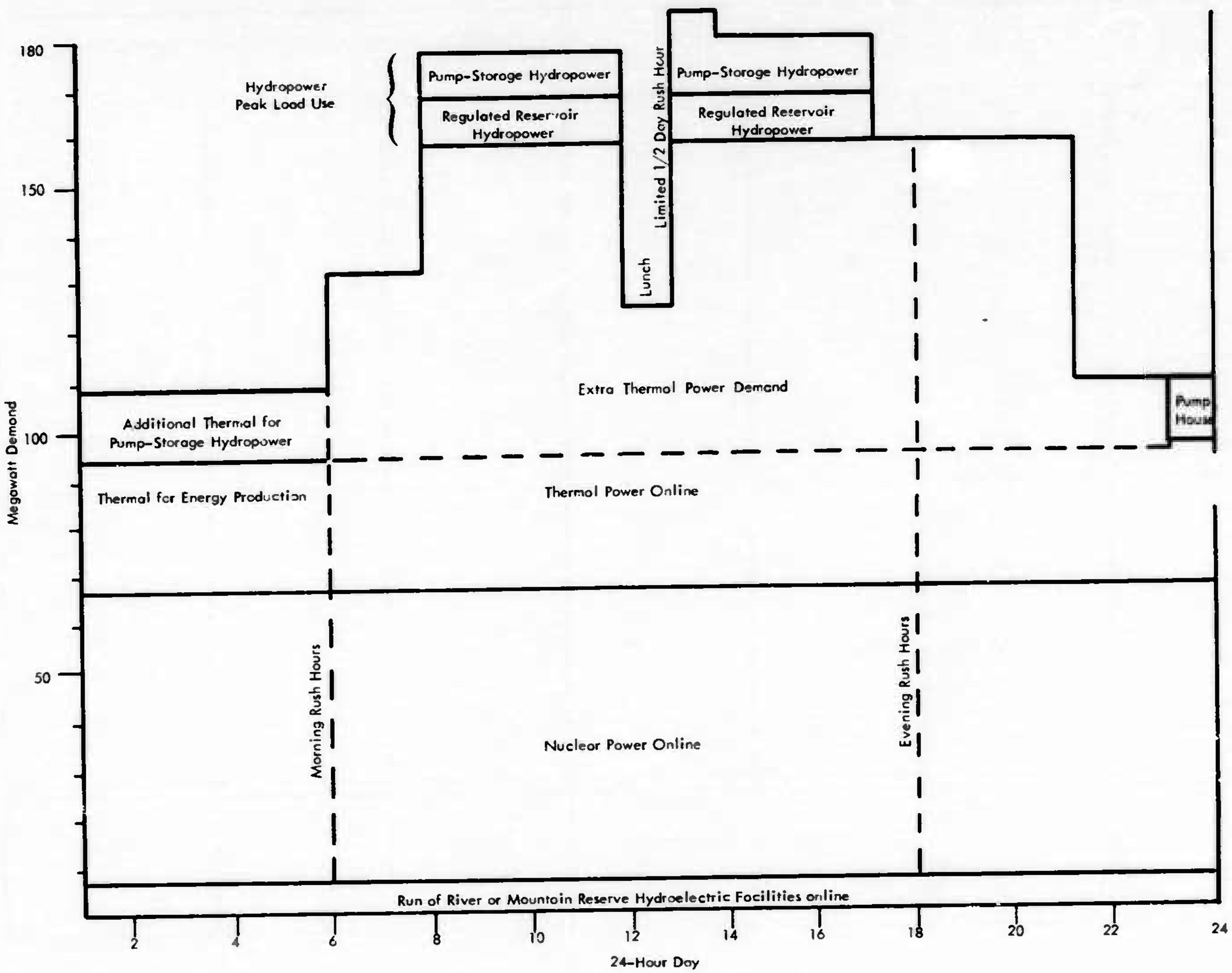

Figure A.4. Postulated Peak Load Conditions, August 1985

Table A.4. Relationship of Hydroelectric Power to Total Electrical Energy Supplies (1960 through 1985)

Year	Total Electrical Energy Supply (10^{12} kilocalories/yr)	Hydroelectric Energy Supply (10^{12} kilocalories/yr)	Percent of Total Electrical Energy Supplied by Hydro
1960	235	143	60.9
1970	721	196	27.2
1975	1,108	213	19.2
1980	1,665	235	14.1
1985	2,450	250	10.2

On the other hand, it may be noted that the forecast contribution of hydroelectric power in 1980 is equivalent to the national total electrical energy supply of 1960! Only if the most stringent constraints on oil availability and use are combined with a massive hydroelectric building program and a complete turning from environment constraints (as well as potential seismic constraints) on the establishment of vast new reservoirs, may hydroelectric power be expected to assume more than approximately 10 percent of the national supply by 1985.

A final option, and one that is not considered likely at this writing, is an extensive upgrading and rebuilding of obsolete and obsolescent hydroelectric facilities. This option could involve the adoption of advanced technology plants on old sites; enlarging of dam and reservoir facilities; installing more modern turbines and generators; and even clearing out silted intakes or reservoir pools. Such operations would be expensive and would probably only be undertaken if other options either became economically unacceptable, or sufficient alternative energy sources became unavailable. If Prime Minister

Tanaka's plan for construction of a large number of multi-purpose flood control and water supply dams is implemented, the percentage of hydroelectric contribution to national electrical energy assets may increase slightly.

Appendix B

JAPAN COAL BUDGET FOR 1971 WITH DEMAND/CONSUMPTION PROJECTIONS TO THE YEAR 2000

B.1 Introduction

The purpose of this analysis of Japan's coal budget and allocations for 1971, and the accompanying projections of coal requirements and consumption to the year 2000, is to show how coal is needed and used in Japan, how it can be related to other energy sources and resources of that country in terms of quantity and energy content for both domestic and imported coal, and how it may be expected to fulfill energy demands between now and the end of the 20th century. Additional comments are offered on implications of Japanese requirements for the U.S. coal industry and on potential technological changes or improvements relating to the role of coal in the production of energy. This appendix is intended to summarize the classes of information included under the various headings. It is not an analysis of the coal industry, the economy of Japan, the desirability of technological changes, nor world foreign exchange problems. Its intention is limited to providing perspective rather than complete topical evaluation.

The information presented in this brief is from two principal sources: U.S. and Japanese. First is the National Coal Association, Coal Building, Washington, D.C., and its many publications, chief among them World Coal Trade, 1972 Edition,[7] from which most of the hard data on exports and imports are available. Other NCS pamphlets and brochures have also been used for background information, and it is here acknowledged that without these NCA data and ancillary conversations with NCS officials this study would not be possible in its present form. The second principal source is Energy in Japan, Quarterly Report No. 19, December 1972,[5] published by the Institute of Energy Economics, Tokyo, Japan. This source contains detailed breakdowns of energy demand and consumption in Japan, and is the most comprehensive compendium seen of the internal characteristics of Japan's energy systems. Some use also was made of parts of Electric Power Industry in Japan 1972, published by Overseas Electrical Industry Survey Institute, Inc. in Tokyo.[1]

The unit of energy used throughout this appendix is the kilogram-calorie. One kologram-calorie (KCal) is the heat required to raise the temperature of 1 kilogram of water from 20° to 21° Centigrade, and is equal to approximately 3.968 British thermal units (Btu). One net (short) ton is 2000 pounds. One metric ton is 2204 pounds or 1000 kilograms. Average energy content of all Japanese coal is 6462 KCal per kilogram,[8] and all imported coal is 7700 KCal per kilogram.[9]

B.2 Data for 1971

B.2.1 Domestic Production

During the calendar year 1971 Japan produced the following amounts and types of coals from within the home islands:[3]

• Cooking coal	$13,520 \times 10^3$ tons (metric)
• Coal for boiler use	$19,414 \times 10^3$
• Anthracite and natural coal	498×10^3
Total	$33,432 \times 10^3$ tons (metric)

In addition, Japan produced 148 x 10^3 metric tons of lignite, which is generally not considered by Japanese sources in demand and consumption statistics. It is speculated that most or all of this lignite goes toward the satisfaction of small consumer demand, such as household heating and cooking, and public baths. Energy content of coals produced amounted to approximately 0.218 x 10^{15} kilocalories.

B.2.2 Imports

Throughout calendar year 1971 Japan imported coal from many source countries[7] amounting in all to 51,709,661 short tons or 46,910,228 metric tons, distributed as shown in Table B.1.

Table B.1. Source Countries for Japan's Coal (net short tons)

Source	Anthracite	Bituminous	Total
United States	10,537	20,364,963	20,375,500
Australia		18,287,168	18,287,168
Canada	182,887	7,288,435	7,471,322
USSR	37,900	2,698,407	2,736,307
Poland		1,265,252	1,265,252
North Viet Nam	451,340	2,094	453,434
China (Mainland)	379,477		379,477
South Korea	355,504		355,504
South Africa	251,428	594	252,022
North Korea		75,032	75,032
Mozambique		45,239	45,239
India	4	12,182	12,186
Other Countries	1,212	6	1,218
Grand Totals	1,745,321	49,964,339	51,709,661
(Equivalent tons metric)	(1,583,329)	(45,326,899)	(46,910,228)

These data can be broken down further on the basis of suitability for end use in Japan, such as direct coke manufacture and blending with other coals for coking. Moreover, information on cost per net short ton affords some idea of the value of various categories of coal on the world market.

The prime category, "Heavy Coking Coal," is divided into two classes: (a) ash content 8 percent or less, and (b) ash content over 8 percent. Shown in Table B. 2 are the data on 1971 Japan imports of these coals, in millions of short tons.

Table B.2. Heavy Coking Coals

Source	Ash ≤ 8%	Ash > 8%
United States	16.1	2.2
Austrailia	2.7	9.1
Canada	1.3	5.0
Poland	1.1	
USSR	0.979	1.3
Totals	22.2	17.6
Average Value/Ton	$26.09	$19.35

The remainder of imported coals fell into the second category, called "coals for coking," with a similar division into classes depending upon ash content. Given in Table B. 3 are the data on 1971 Japan imports of these coals, in millions of short tons.

Table B.3. Coals for Coking

Source	Ash ≤ 8%	Ash > 8%
United States	1.9	
Austrailia		6.6
Other	1.2	0.37
Totals	3.1	7.0
Average Value/Ton	$23.07	$16.57

The fact that the totals of the two tables above do not quite add up to the total imported is due to severe rounding of totals in some cases, and to diversion of minor quantities to non-coking uses. Total energy content of all imported coals amounted to approximately 0.362×10^{15} kilocalories. Figure B. 1 presents a detailed balance of coal supply and consumption for 1971.

B. 2. 3 Japanese Consumption

To the $33,432 \times 10^3$ metric tons of Japanese coal production, and the $46,910 \times 10^3$ metric tons of imported coal, must be added two minor increments from stockpile or from shipping bottoms in transit — to equal the overall consumption of coal by Japan in 1971. Put in tabular form, the weights and energy contents appear in Table B. 4. From this foregoing array, and more particularly from calculations performed on myriad data presented in Reference 3, it is clear that aggregated energy contents for Japanese and imported coals approximate the following mean values:

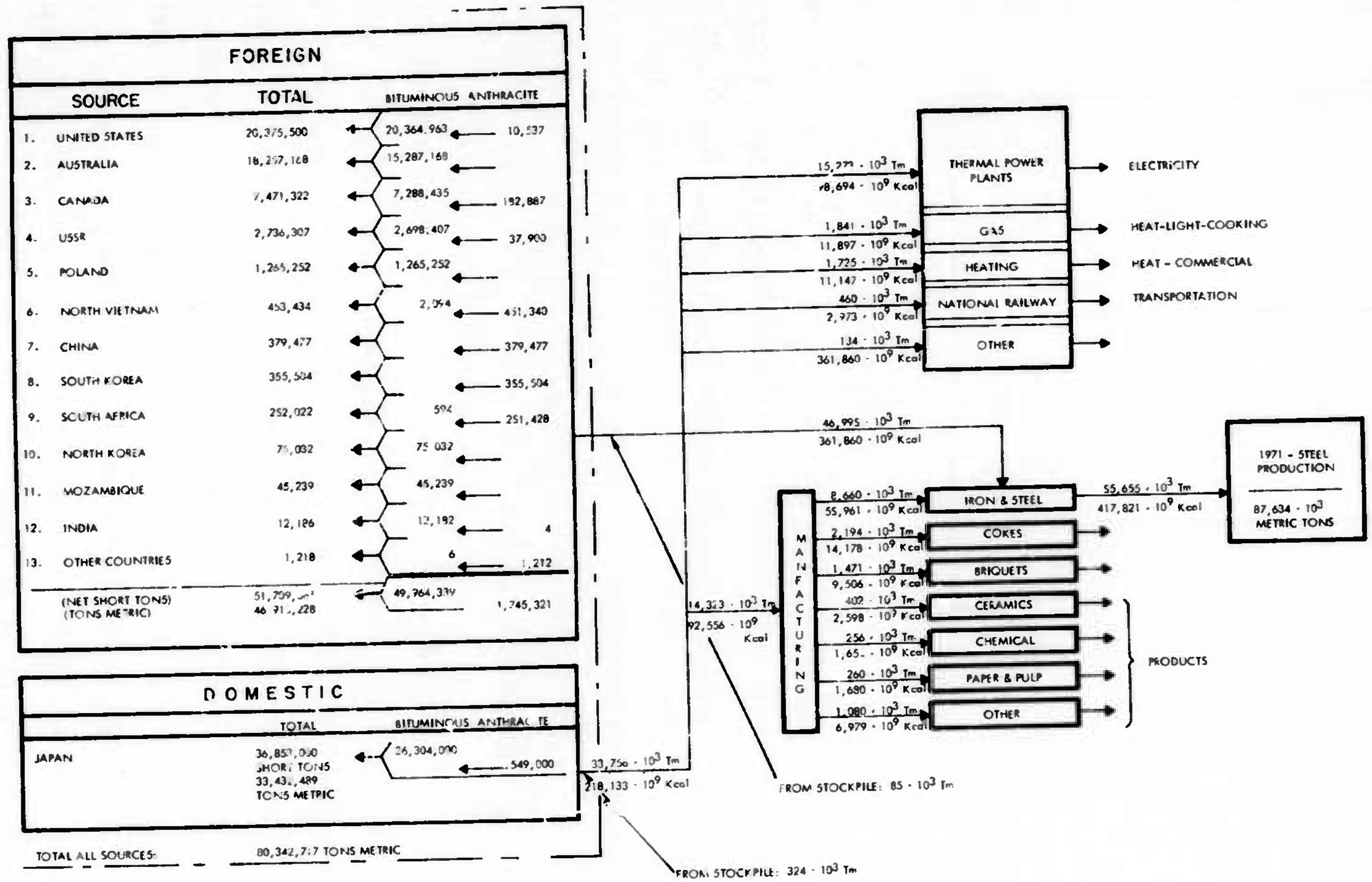

Figure 5.1. 1971 Coal Budget for Japan

- All Japanese Coal: 6462×10^3 kilocalories/ton metric
- All Imported Coal: 7700×10^3 kilocalories/ton metric

These mean values have been used as conversion factors for energy calculations throughout this appendix.

Table B.4. Overall Consumption of Coal by Japan

	Quantity (10^3 metric tons)	Energy Content (10^9 kilocalories)
Japan production 1971	33,432	
Japan "stockpile"	324	
TOTAL	33,756	218,133
1971 Imports	46,910	
"In-transit"	85	
TOTAL	46,995	361,860
GRAND TOTAL	80,751	579,993

B.2.4 Allocations of Coal Consumption

Of the $80,751 \times 10^3$ metric tons of coal consumed in 1971 containing approximately $579,993 \times 10^{12}$ kilocalories, allocations were as shown in Table B.5. Noteworthy in these allocations is the fact that the Japanese iron and steel industry alone consumed all imported coal plus a quantity (8.6 million tons metric) of domestic coal second only in size to the electric power industry. The total coal requirement, 55.6 million tons metric, allocated to the iron and steel industry resulted in the production of $87,634 \times 10^3$ metric tons of steel

Table B.5. Coal Consumption Allocations

Use	Quantity (10^3 metric tons)	Energy Content (10^9 kilocalories)
Thermal power plants	15,273	98,694
Gas (household, etc.)	1,841	11,897
Heating (commercial)	1,725	11,147
National railway	460	2,973
Other	134	866
Manufacturing		
Iron and steel	55,655	417,821
Cokes	2,194	14,178
Briquets	1,471	9,506
Ceramics	402	2,598
Chemical	256	1,654
Paper and pulp	260	1,680
Other	1,080	6,979

during 1971, down somewhat from $93,259 \times 10^3$ metric tons of steel produced in 1970.

B.3 Projections to the Year 2000

B.3.1 Japan's Coal Demand

Japan's demand for coal (Figure B.2) for the base case is visualized as nearly tripling during the period 1971-2000, but decreasing from 18.24 percent of the total 1971 energy budget to something on the order of 10 or 11 percent of total energy consumed in 2000. In energy terms in the base case coal would increase from 0.58×10^{15} KCal in 1971 to approximately 1.60×10^{15} KCal in 2000, measured against a total energy demand of 4.3×10^{15} KCal in 1971 which is projected to 15.3×10^{15} KCal in 2000. In the base case, the shift in

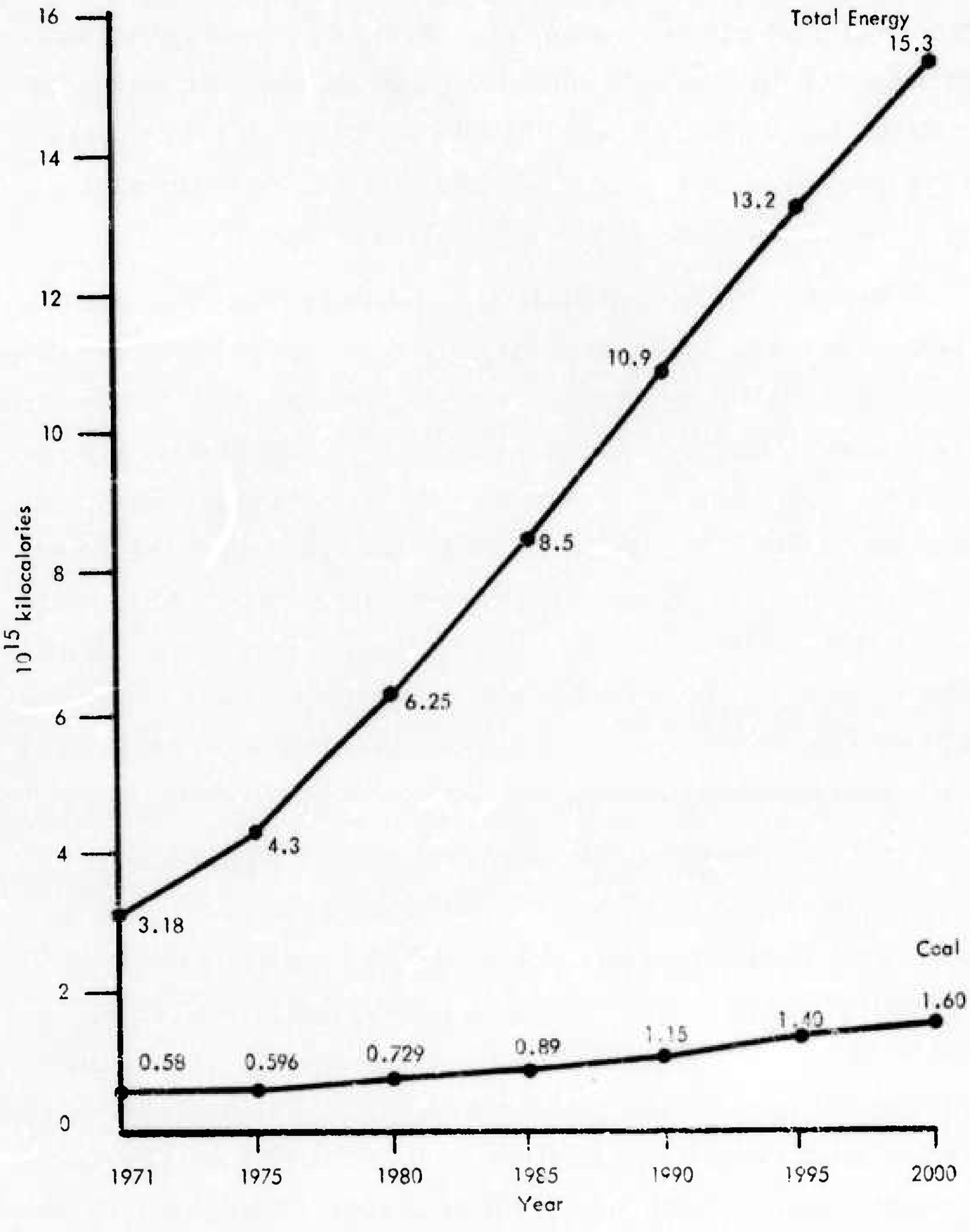

Figure B.2. Projection of Base Case Coal Requirements in Relation to Total Energy Demand, 1971-2000 energy consumption to the household and residential sector and away from the industrial sector will mean a decreasing reliance on coal as a fraction of total energy consumption. Further, environmental considerations will increasingly mitigate against unrestrained expansion of coal-burning plants until new technologies of flue-gas desulphurization can be utilized on a large scale, and nuclear power will also replace coal as a source of base load electrical power.

Representative allocations of coal energy to various consuming sectors of the Japanese economy were developed for 1971, as shown in Figure B. 1. All values discussed below, in units of 10^{15} kilocalories, are projections based upon the base case overall coal demand projections as well as plausible and verifiable trends and relationships for each of the individual consuming sectors. An iterative procedure was employed in which the trends of each sector were considered in light of Japanese projections, information developed in the course of the current study, and overall coal supply estimates (domestic production plus foreign imports). The following considerations were used in allocating coal to individual sectors.

Thermal Power Plants. Consistent with the phase-out of coal-fired electric power generation that began around 1967, and the concommitant emphasis on oil-fired plants, 1971 saw a low of 0.0987 (10^{15} KCal) of coal utilized for thermal power, down from roughly 0.1695 in 1967. Although both economic recession and conversion to oil affected the 1971 thermal power consumption, it is projected that the requirement for coal will probably be 0.100 in 1975 as it peaks out at approximately 0.122 in both 1980 and 1985. Following this, as existing equipment is replaced and new investment tends toward nuclear power technology, coal requirements will taper off to about one-half of the 1985 value or 0.060 in the year 2000.

Transportation. Now going to the Japan National Railways (JNR) in minor quantities, the 0.003 x 10^{15} KCal of coal utilized in 1971 will decrease to 0.002 in 1975, 0.001 in 1980, and to virtually nil after that as existing equipment is scrapped, particularly shuttle and yard steam locomotives burning coal. Some separate coal-fired generator plants may still serve yards and spurs but will be phased out as the national power grid is augmented.

Non-Energy Uses. Acutely sensitive to economic vicissitudes, the use of coal as a hydrocarbon resource by the Japanese chemical industry fell to 256 x 10^3 tons metric, or 0.0017 x 10^{15} KCal in energy terms, from 801 x 10^3 tons metric in 1969, which may have marked the culmination of a post-World War II cycle of expansion of productivity and marketing. By-product distillation of coal, besides coke, ammonia, and coal gas, yields the so-called light and heavy oils (containing benzene, toluene, xylene, solvent naptha, naphthalene, carbolic acid, cresols, phenols, and pyridines to name a few) which in turn are the chemical basis for much that civilization desires, including dyes, explosives, fertilizers, insecticides, detergents, plastics, drugs, pharmaceuticals, solvents, insulators, fire retardants, synthetic rubber, refrigerants, and nylon, which is not to mention perfumes and nail polish. Although competition is intense between the industrialized countries, Japan will undoubtedly gain a substantial share of the business of the presently emerging and underdeveloped countries, such that requirements of 0.002 (10^{15} KCal equivalent) can be projected for 1975 with a gradual increase to 0.004 for the year 2000, bearing in mind in every case that these data are for coal as raw material, not an energy source. Some stockpiling of coal by the chemical industry is assumed, influencing requirements for 5 to 10 years.

Iron and Steel. As a generalization, the production of one ton of steel requires 2/3 ton of coal and 20 tons of water, but these conversion factors may change substantially in the next decade or so. Newer techniques of smelting involving greater efficiencies of oxygen introduction and treatment can diminish the amount of coal or coke necessary to the process. But if less coal per ton of steel is required, the countervailing fact remains that Japan, already a major steel producer, will probably provide the basic steel, both structural and fabricated, in support of intense economic development in Asia and elsewhere through the next several decades. Therefore, it is probable that Japan will recover from its recession-associated 0.418 (10^{15} KCal) of 1971 to 0.430 in 1975 (100×10^6 short tons of steel); 0.531 in 1980; thence to 0.666 in 1985, 0.900 in 1990, 1.121 in 1995, and culminating in 1.229×10^{15} KCal in the year 2000.

Residential-Commercial. Coal is used for direct heating by burning, and also the manufacture of gas to go directly into the mains for heat, light, and cooking. This latter, the so-called "coal gas," is not the same product contemplated by large-scale coal gasification, now undergoing intensive research and development in the United States. Instead, it is simply an oven gas resulting from baking or carbonization of coal. Projections must consider not only research progress within the coal industry, but the role of petroleum gases, particularly LNG (liquified natural gas) imports in an era of developing transport technology. In 1971 coal allocations to "gas," "heating," and "other" in combination amount to 0.024 (10^{15} KCal), which will increase slightly to 0.026 in 1975, and then jump moderately to 0.033 in 1980 as Japan's burgeoning population demands more gas for residential needs simultaneously with a requirement for coal for heating new building in new cities. By 1985 0.039 KCal will suffice, representing a slight diminishing in the overall rate of increase. Following this, however, gasification technology should be operating on a large enough scale in Japan to accelerate the rate of increase in coal requirements to 0.047 in 1990; 0.056 in 1995; and 0.067 in the year 2000.

Other Industrial. All other industrial uses of coal, amounting to 0.0353 x 10^{15} KCal (5.46 x 10^{6} tons metric) in 1971, which can be expected to increase by a factor of 6 or 7 in the following three decades. Japan's economic survival is recognized as being a matter of importing commodities, processing them, and then selling manufactured products at all levels of technological sophistication, from electronics down to charcoal briquets and ceramic brick, tile, and pipe. New manufacturing capacity will accompany increases in population and the formation of new settlements and transportation centers representing loci of new production facilities, particularly as Japan services growing markets for low- and medium-technology products necessary to the development of emerging countries. Coal requirements will increase for industry (exclusive of chemicals and steel) to 0.036 (10^{15} KCal) in 1975; 0.06 in 1985; and then accelerate to 0.10 in 1990; and 0.24 in the year 2000.

B.3.2 Domestic Production

Japan's coal resources,[8] amounting to approximately 9.894 x 10^{6} metric tons, are distributed primarily in Hokkaido, Kyusku, and northeast central Honshu, or in other words from one end of the country to the other, requiring extended transportation (rail) networks for shipment to centers of consumption. Coal seams ranging down to 0.3 meters thick are inventoried as resources, but Japanese seams are irregular in thickness and geometry because of relatively severe geologic deformation and intrusion in many places by igneous rocks. Consequently mining and productivity are at once difficult and a function of engineering skill, a condition that will intensify as demands increase on the domestic supply of coal. After 1985, however, a transfer of technology from the United States could afford something more than a dousing of production, Figure B. 3, as ways are found to combine U.S. high-speed mining techniques with methods for overcoming undependable floor and roof conditions, spalling problems, and irregular seam geometry. Moreover, various augering and boring systems will be applied to seams too thin to enter. Thus Japanese coal production, at an average of 6462 KCal/kilogram, will change only slightly from 0.218×10^{15} KCal in 1971 to 0.24 in 1985, but over the next 15 years from 1985 to 2000 will more than double to 0.5×10^{15} KCal.

B. 3. 3 Imports

The difference between Japan's coal production and total coal requirements will be met by increasing that country's rate of coal importation from its present suppliers throughout the world, particularly the United States, Australia, and increasingly, mainland China. Using 7700×10^3 KCal/ton metric as the mean energy content of imported coal, it is clear that imports will approximate the total energy content and tonnages given in Table B. 6. No question exists but what these import targets can be satisfied from world coal resources, and it is safe to say that at prices (delivered) averaging very roughly at \$20.00 per net short ton, or \$22.00 per metric ton, at 1971 monetary values, any number of countries will be happy to sell coal to Japan in order to earn international exchange credits vis-a-vis Japan, whose exports have

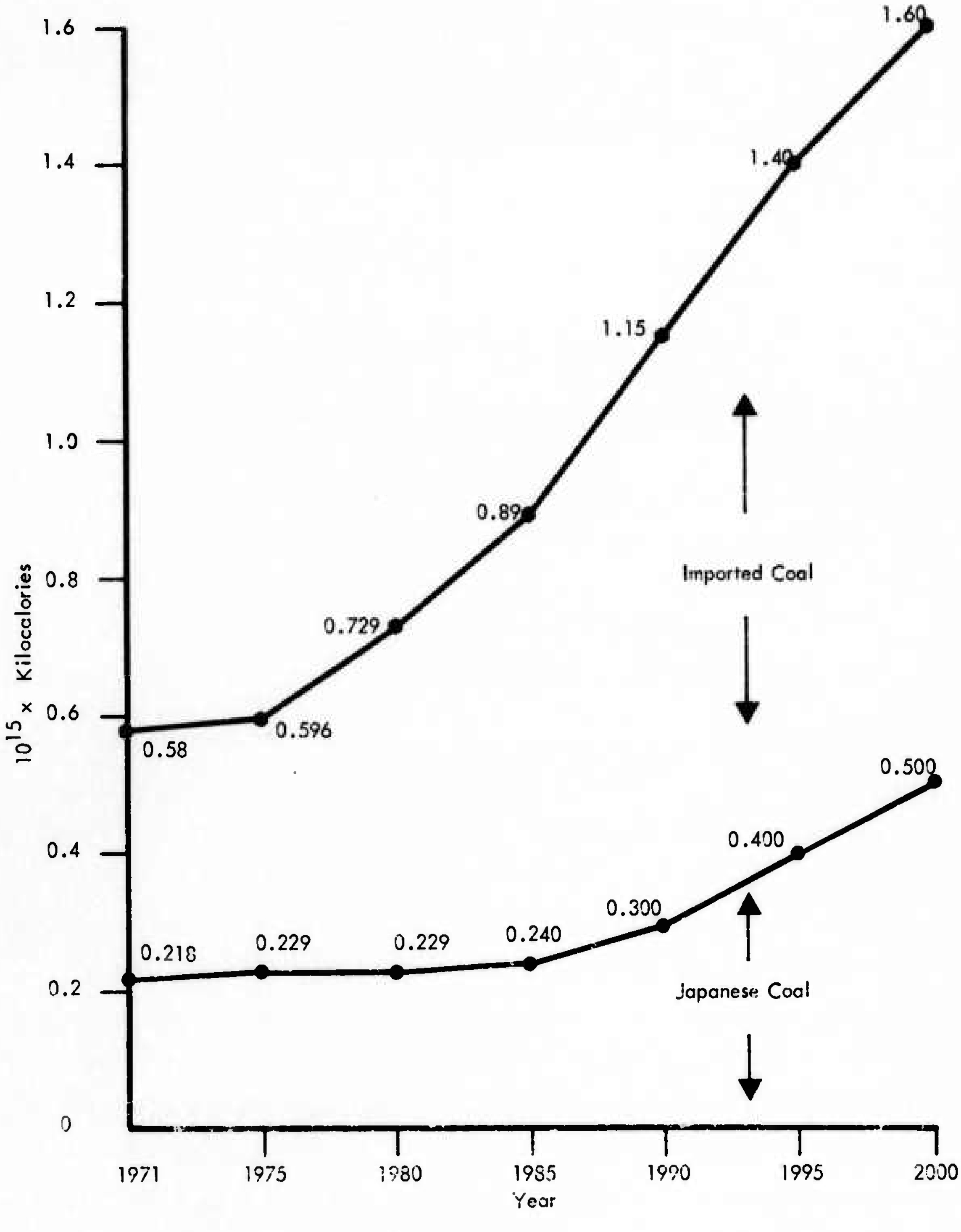

Figure B.3. Projection of Size and Composition of Japanese Coal Requirement, 1971-2000

Table B.6. Coal Import Projection

Year	Quantity (10^6 metric tons)	Energy Content (10^{15} kilocalories)
1971	47	0.362
1975	48	0.367
1980	65	0.500
1985	84	0.650
1990	110	0.850
1995	130	1.000
2000	143	1.100

been welcome. For example, more than $1 billion (in 1971 dollars) worth of coal will be needed in 1975 alone. It should be emphasized, however, that these prices represent delivered coal in Japan, and these include an increment of cost, and profit, accruing to the Japanese shipping industry as it transports coal in Japanese bottoms, or colliers.

All the above discussions have been made assuming the base case projection of energy demand. In the low case, requirements for coal would be reduced somewhat, and in particular the incentive to increase production of low grade domestic coal would be greatly reduced. As a consequence domestic production would increase only slightly through year 2000 and coal imports would be only about 20 percent lower than in the base case. In the high demand case the continued industrial growth will require substantially larger amounts of coal than in the base case, as shown in Figure B.4. By year 2000 the demand for imported coal in the high case would be 2.6×10^{15} KCal or 338×10^6 metric tons of coal a year. This amount is not enough to threaten world coal reserves, but it would represent a 7.5 billion dollar a year business at today's prices.

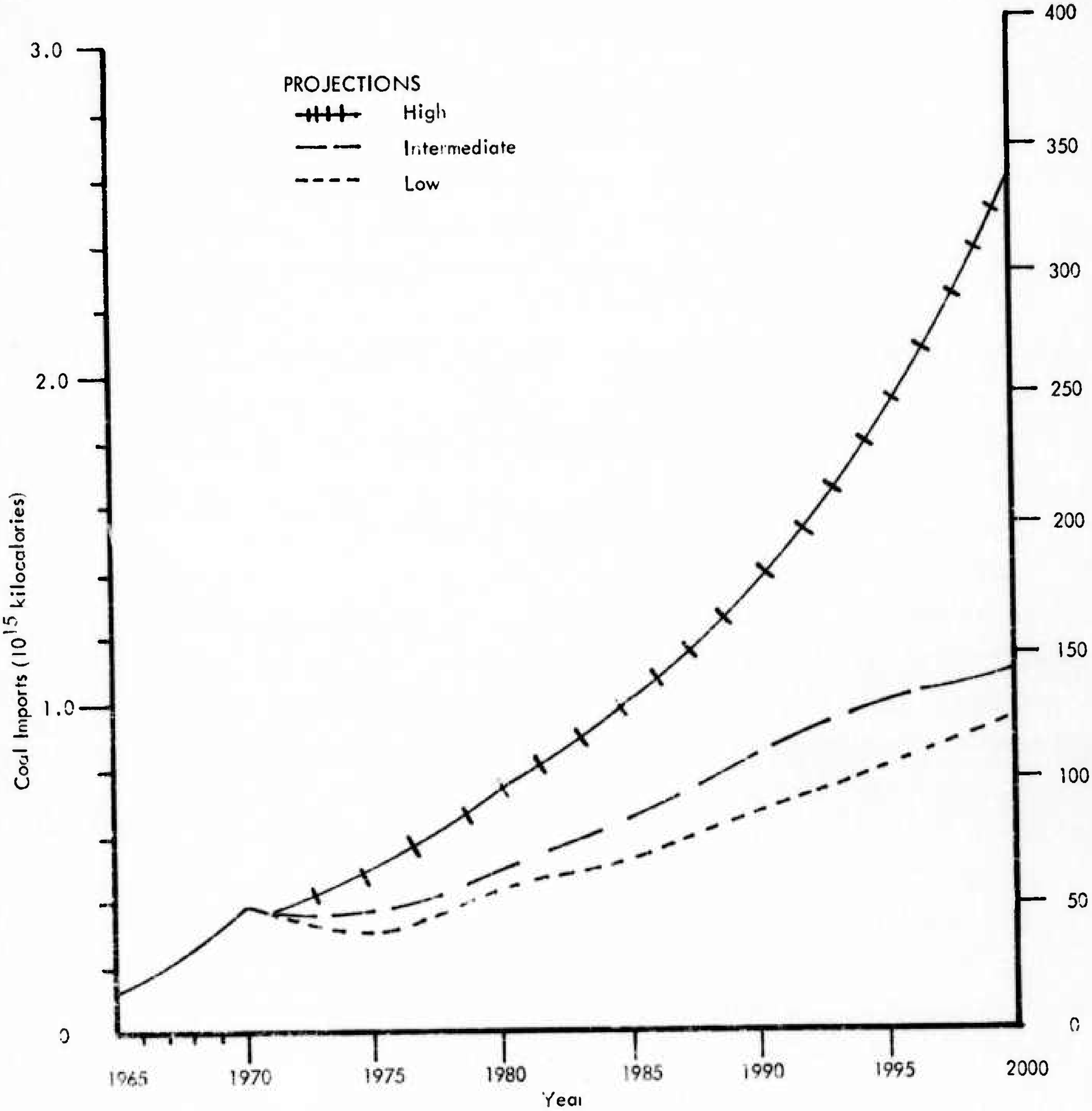

Figure B.4. Imported Coal Requirements for Japan for Different Cases

B. 3. 4 Implications for the U.S. Coal Industry

As the world's largest coal exporter, the U.S. has a very heavily vested interest in protecting its markets, based upon investment in mine-openings, mine equipment and technology, payrolls, transport facilities, and marine terminals and transshipment points. In that the United States has the world's most extensive coal reserves, 2.4 trillion tons at depths of 3000 feet or less, and is the world's greatest coal producer, 555.5 million short tons (504 million tons metric) in 1971, it would seem that the rising Japanese coal demand represents very favorable possibilities both for the U.S. coal industry itself and, more generally, for the U.S. balance of payments situation with Japan. It should be noted as well that Japan's swelling coal requirements between now and 2000 represent a prime marketing target for the United States, provided the world economy remains reasonably healthy and Japan continues to produce steel. As Japan's imports increase, the U.S. can strive for a growing proportion of the total coal needed based not only on resources and existing facilities, but on the relative financial and technical ease with which deliveries can be expanded. This is to say that capital flexibility is still one of the great strengths of the United States, quite disproportionately to the positions of the USSR and China as other eligible, and presumably interested, suppliers. Australia, now the chief competition to the U.S. in coal exports to Japan, is finding growing markets in Europe and South America, and probably will not be able to match the U.S. in consumption of Japanese products. Japan has political reasons for building reciprocal trading arrangement with both China and the USSR, and compelling economic reasons for consolidating its position with the U.S. so as to satisfy trade needs in both directions. Australia is slightly less important to Japan on the basis of pure politices as well as pure economics, but itself has great capital flexibility, similar to the United States.

Based on all of the foregoing, it would appear that the U.S. might aim for long-term contracts building toward 100 million metric tons per year in 2000 for Japan alone, from the 18.5 million tons metric in 1971, based upon: (a) splendid resources; (b) a very sophisticated extractive technology; and (c) capital flexibility and availability. From 1975 to 2000 approximately 1.5 billion tons metric of U.S. coal could be sold to Japan at perhaps $30 billions net of today's dollars, provided the U.S. remains competitive in the world coal market.

B.4 Potential Technological Improvements

B.4.1 High-Speed Mining

U.S. leadership in world coal production and trade is based not only upon a large supply but upon very favorable geology. U.S. coal seams are relatively thick, generally nearly horizontal, and at shallow depths compared to much or most foreign coal. Furthermore, large quantities of coal are a short distance from Atlantic ports and/or easily accessible to Gulf Coast ports. With competent floor and roof conditions, U.S. seams have been mined by machine methods of increasing speed, technology, and managerial sophistication. Indeed, operations research as a management tool appeared in the U.S. mining industry more or less concommitantly with its appearance in the U.S. Department of Defense after World War II. Results in terms of coal production efficiency have been impressive, particularly the unit-shift method of combining men, machinery, maintenance, and time at the working face in such a way as to maximize extraction by carefully planned cycles of cutting, drilling, blasting, and loading using very sophisticated heavy equipment.

Some of this technology is directly transferable to Japan where her coal seams are sufficiently thick, horizontal, and enclosed in adequate floor and roof. Mostly, though, U.S. high-speed mining methods are not readily adaptable to Japanese coal seams. Instead, however, U.S. technological capability, mining doctrine, and attitudes can be transferred. Redesigned heavy equipment, new loading and belt systems, increased use of heavy augering techniques, and specially designed boring or continuous mining machines with self-contained conveyer systems will all contribute to enhanced extractive efficiency from thinner, irregular, and geologically distorted Japanese coal seams. Moreover, such changes will not only decrease labor requirements and increase productivity per man, but will afford the mining of seams without human entry which are now too dangerous to attempt by current, labor-intensive methods.

Finally, it should be noted that in the United States it requires about 12 kilowatt hours(9) to mine a ton of coal by current methods. Assuming approximately 35 percent efficiency, this translates into 32,516 KCal/metric ton, which would mean for Japan that a little more than 5 kilograms of coal per ton would be consumed in order to provide the electricity to mine with a technology comparable to that of the U.S. Although this is not much at first glance, it would amount to 2.5×10^{12} KCal in order to mine 0.5×10^{15} KCal worth of coal in the year 2000, or nearly 387,000 tons to pay for the electricity.

B.4.2 Flue-Gas Desulphurization

A principal objection to the burning of so-called "steam" coal in order to generate thermal power is air pollution caused by sulfur dioxide (SO_2) released by burning into the atmosphere. If a way is found to prevent this escape, then sulfur-containing (generally 3.5 percent) steam coal is not objectionable as fuel. Intensive research is underway[10] in many industrial laboratories to find methods of counteracting this problem, including various kinds of chemical processing, additive injection, catalytic oxidation, and sorption on solid reagents. In laboratory or bench-model studies, or even small-scale pilot-plant investigations removal efficiencies are in the range from 70 to 90 percent, but full-scale operation, and accompanying investment, are required in order to understand true cost and amortization characteristics. The Japanese themselves are working on the problem and have gone beyond the pilot-plant stage in a process of injection of gaseous ammonia to the hot flue gases containing SO_2 to form an end product of ammonium sulfate suitable for agricultural use as a fertilizer.

All in all, there seems little doubt that flue-gas desulphurization on an industrial scale will ultimately occur, but at what cost and efficiency for power plants of varying size, age, location, fuel, and load pattern remains to be seen. Certainly the development of a successful desulphurization technology could influence Japan's energy production away from dependence on oil toward increased utilization of coal.

B.4.3 Coal Gasification

For many years the idea of converting coal to usable, pipeline gas (900 to 1000 Btu/cu ft) has attracted attention from both industry and the research community as a means of transforming huge known coal deposits into the practical equivalent of natural gas by some reasonably cheap process. Much research[11] has been accomplished in order to demonstrate that such a conversion is possible on a small scale, but full-scale operations are well in the future as some of the more promising pilot projects are only being assembled now in the 1972-73 period. In brief, the gasification processes involve joining hydrogen (H) from water (H_2O) with Carbon (C) from coal to form methane (CH_4), a highly suitable gaseous product, all of which is accomplished in an oxygen environment in order to maintain high temperatures as the oxygen combines exothermically with carbon to form carbon monoxide (CO) or carbon dioxide (CO_2) as by-products. As neat as the chemistry may appear, the practical problems of performing such a transformation on a large scale go deeply into industrial stoichiometry and process engineering, and involve other reagents such as limestone or dolomite as well as coal and water. Problems of control of temperatures, reagent composition, thermodynamic variation, reactor-vessel design, desulfurization, catalytic reactivity, and atmospheric emissions are all being worked out at pilot-plant level for purposes of optimization of several competing systems jointly established by the U.S. Department of Interior Office of Coal Research and various private-sector industrial companies. An overwhelming consideration is the determination of costs, equipment deterioration, amortization, and from all of these, the fundamental capital requirements and capital sources for such large-scale energy conversion. Moreover, although the assumption prevails that "gas is good," further systems studies of large-pipeline economics will necessarily have to be performed in the United States for gas transmission and utilization for the period 1980-2000.

At present, pilot operations on the order of 50 to 100 tons of coal per day are starting up which are projected to produce 1 to 2 million cubic feet/day of high-energy gas. After exhaustive pilot-plant analyses and evaluations, planning for full-scale utilization of coal resources will be possible.

There seems little doubt in mid-1973 of the ultimate success of U.S. technology in coal gasification for pipeline transmission to established gas utility companies, but it is too early to fix upon schedules, deadlines, and target dates, other than to suggest fruition in the 1980s. There is less question as to whether coal gasification will become a reality than as to when.

Granting the energy requirements of Japan through the end of the century, and the cost/benefit awareness of the Japanese in operating their economy as one big consolidated national factory, there is no question that large, dependable coal resources in the United States, through a Japanese investment in coal gasification (either in the U.S. or Japan) could contribute significantly toward offsetting an increasing dependence on imported petroleum as a source of energy.

Appendix C

JAPANESE PETROLEUM DEMAND AND RESOURCES

C.1 General Summary

A major factor in enabling Japan to make such a remarkable post-World War II economic recovery and to achieve the world's highest rate of economic growth over the past 15 years has been stable availability of and economically priced foreign oil. Oil made up about one-third of Japan's primary energy supply in 1960 and rose to represent more than two-thirds of the primary energy supply in 1971; the percentage has been estimated to reach 75 percent by 1975, and significant declines in oil's percentage of the country's energy demand budget are not expected until later in the century. Because 99 percent of Japan's oil is imported, Japan is the most susceptible nation in the world to economic distress and serious national problems in the event of major disruptions in the international oil industry.

Throughout the period to the end of this century, Japan's principal efforts with respect to oil will be to increase its security, control, and diversification of foreign oil sources. In spite of a large and continuingly aggressive program to secure control of a substantial portion of its supplies, it is expected that within the period under study Japan will continue to rely on the Middle East and on foreign oil companies for most of its oil. The future, however, will see rapid growth worldwide of Japanese financing and control of oil exploration, production, and transportation operations.

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The chief sources of international conflicts that may be associated with Japan's efforts are likely to involve conflicting territorial claims in offshore oil basins in the Far East; economic competition with the United States and Western Europe for oil reserves in the Middle East; and possible conflicts arising as major international oil companies are caught between restrictive nationalistic policies of the oil exporting nations and a Japanese policy that might deny them a substantial portion of Japan's oil market.

C.2 Petroleum Consumption and Resources

C.2.1 Current Demand

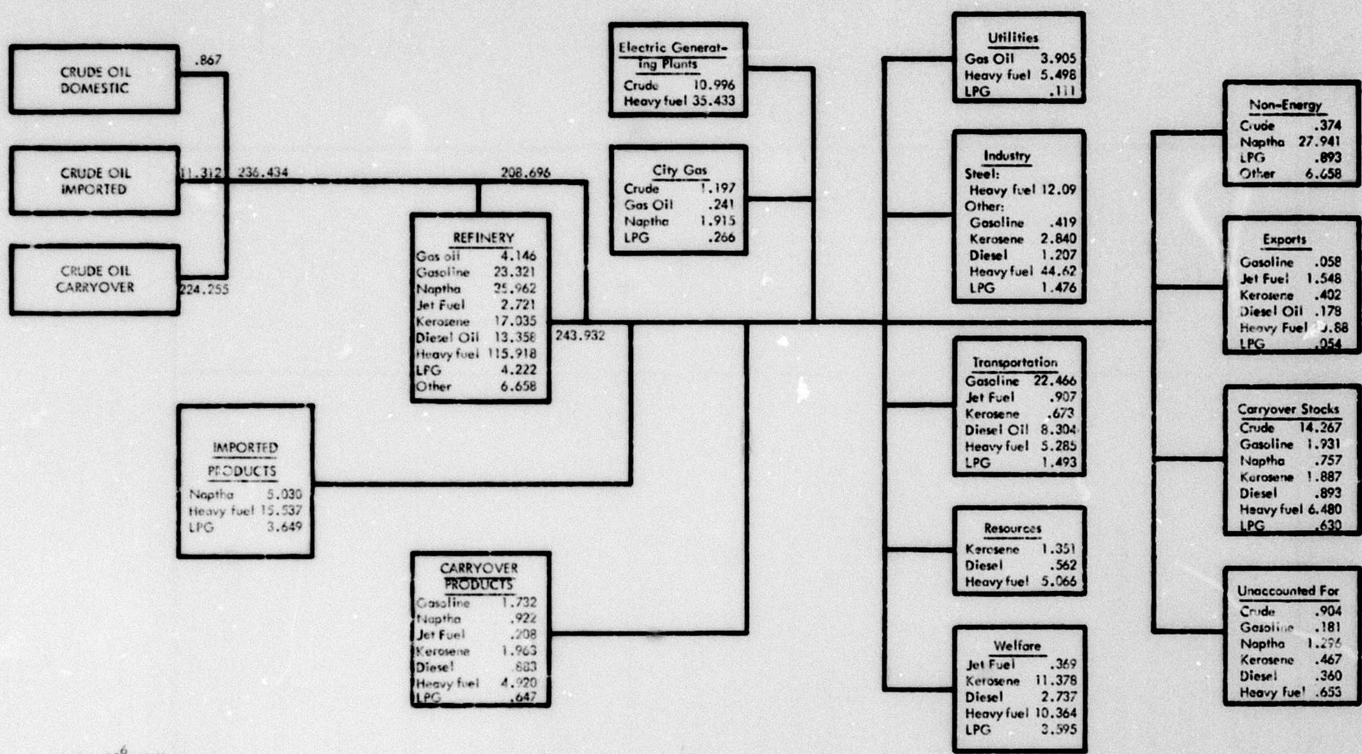
An energy-balance base year of 1971, the most recent year for which complete data were generally available, was adopted for this study. The balance of supply and demand (consumption) of energy derived from oil and oil products for calendar year 1971 is summarized in Table C.1. Considering both the oil products consumed directly and through secondary conversion in the form of electricity, about 45 percent of the total energy consumed from oil went for industrial uses and about 19 percent for household and commercial uses. The pattern of consumption by specific petroleum products for 1971 is shown in Figures C.1 and C.2.

The distribution and consumption of petroleum products, as reflected in official petroleum supply plans, is not expected to see any abrupt changes in the near future. General trends to be expected, however, will be slight decreases in gasoline distillation and increases in naptha and heavy fuel oil. Increased use of LPG in automobiles is expected to continue and to decrease the rate of growth of gasoline demand in the near future.

Table C.1. Japan: Supply and Consumption of Energy from Oil in FY 1971*

	10^{15} kilocalories	
Primary Energy Supply		
Domestic crude oil	0.008	
Imported crude oil	2.108	
Imported oil products	0.241	
Carry over	0.213	
Total Supply		2.570
Consumption		
Electrical generating plants	0.490	
Utilities	0.134	
Industrial use	0.619	
Transportation	0.354	
Resources	0.067	
Household and commercial	0.276	
Non-energy and unaccounted	0.346	
Total consumed		2.285
Exports and Carry Over		
Total exports	0.128	
Carry over	0.256	
Subtotal		0.384
Subtotal		2.669
Gain in refining		-0.099
TOTAL		2.570

* Source: MITI, 1972. (Reference 2)



Units: 10^6 kiloliters
Source: MITI, 1972

Figure C.1. Supply and Consumption of Oil by Consuming Sectors and Products, 1971

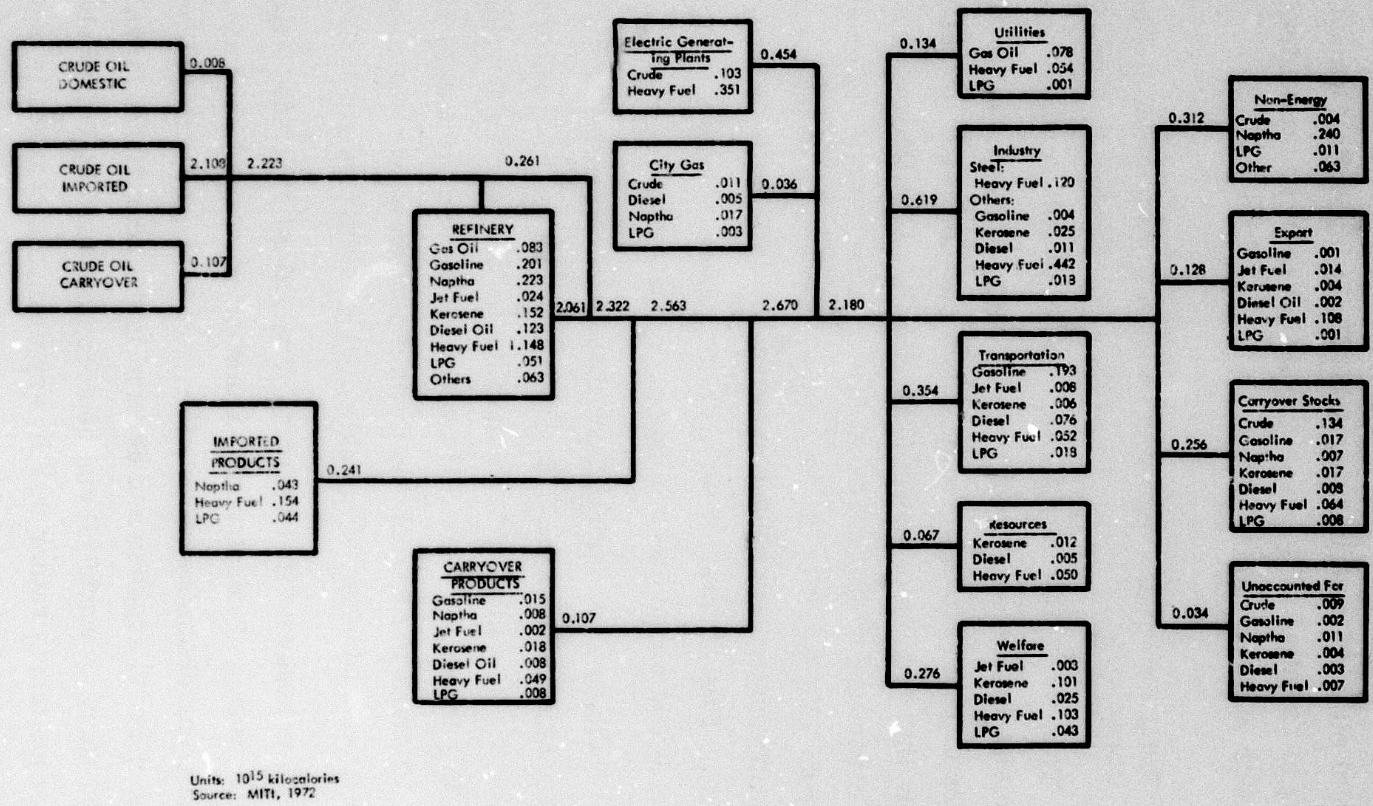


Figure C.2. Japan: Supply and Consumption of Energy from Oil by Consuming Sectors and Products, 1971

The consumption of heavy fuel oil, which makes up 50 percent of the total oil consumed in Japan in 1971, is shown in Figure C.3. (Because of rounding off by differing sources, these totals do not agree exactly with those in other figures.)

C.2.2 Relationship of Japan's Petroleum Consumption to World Consumption

To measure the significance in the growth of Japan's energy requirements that must be met by petroleum, the percentage of total world consumption represented by Japan was computed for the past decade of high economic growth (Table C.2). This table shows that Japan's consumption of petroleum rose by a factor of 6.5 during the period from 1960 to 1971: however, her percentage of total world consumption during this period rose only by a factor of 3 (from 3 to 9 percent). This represents an average annual increase in Japan's portion of world consumption of about 0.5 percent.

The base case energy projections developed for this study and the world projections of the U.S. Bureau of Mines,[12] indicate that Japan's share of total world consumption by the year 2000 would rise to about 15 percent. This would represent an average annual rate of increase of about 0.2 percent in Japan's portion of world consumption, or a 2.5 times reduction of the rate during the period 1960-1971.

This suggests that in terms of world oil demands, Japan even in the year 2000 will require only a modest increase in her share of the world's petroleum supplies. Further, it suggests that at least on the basis of world supplies and demand in the year 2000, Japan's increased share of world oil can be accommodated by relatively slow, gradual adjustments rather than by any dramatic changes in world patterns, as long as Japan is willing to maintain relatively strong dependence

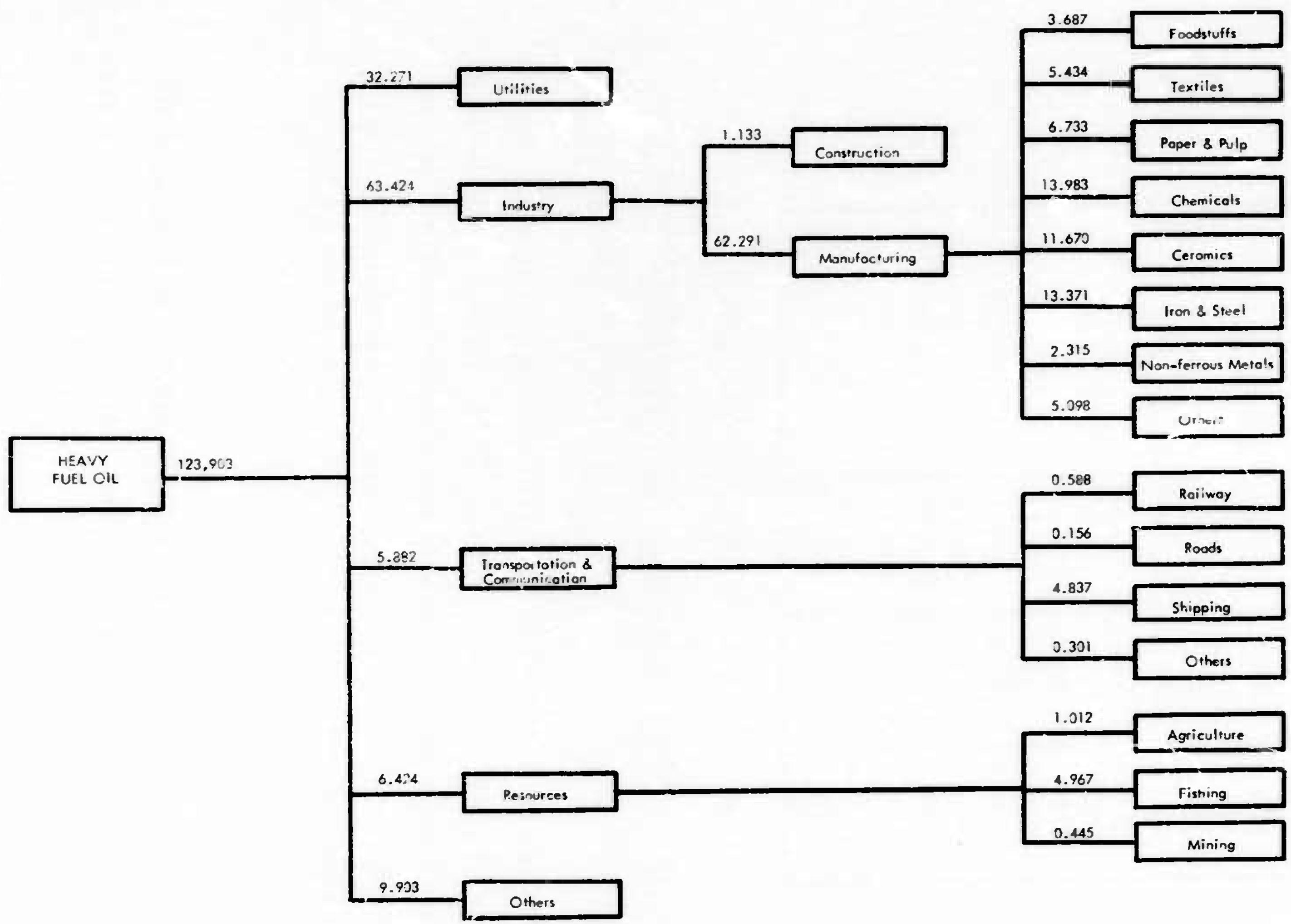


Figure C.3. Japan: Consumption of Heavy Fuel Oil by Industries, 1971

Table C.2. Japan's Share of World Petroleum Consumption, 1960-1971 and 2000

Year	World (10^6 KL)	Japan (10^6 KL)	Percentage of World Consumption
1960	1276.5	39.42	3
1961	1361.4		
1962	1473.6	55.38	4
1963	1581.8	71.89	5
1964	1706.1	88.33	5
1965	1828.6	103.47	5
1966	1780.5	117.47	6
1967	2131.9	140.09	7
1968	2323.4	143.24	6
1969	2502.6	192.86	8
1970	2738.4	237.44	9
1971	2886.7	250.00	9
2000	6520.0	979.0	15

Source: Historic data — IPE, 1972; USGS, 1973 (References 13, 15)
Projections — BuMines, 1970; this study (Reference 12)

on the traditional oil exporting areas for its supply and assuming that total world demand can in fact be met. Note, however, that if the high case projections were met, Japan's share of total world oil demand would increase to about 30 percent, which could drastically affect world oil supply patterns.

C.2.3 Domestic Sources

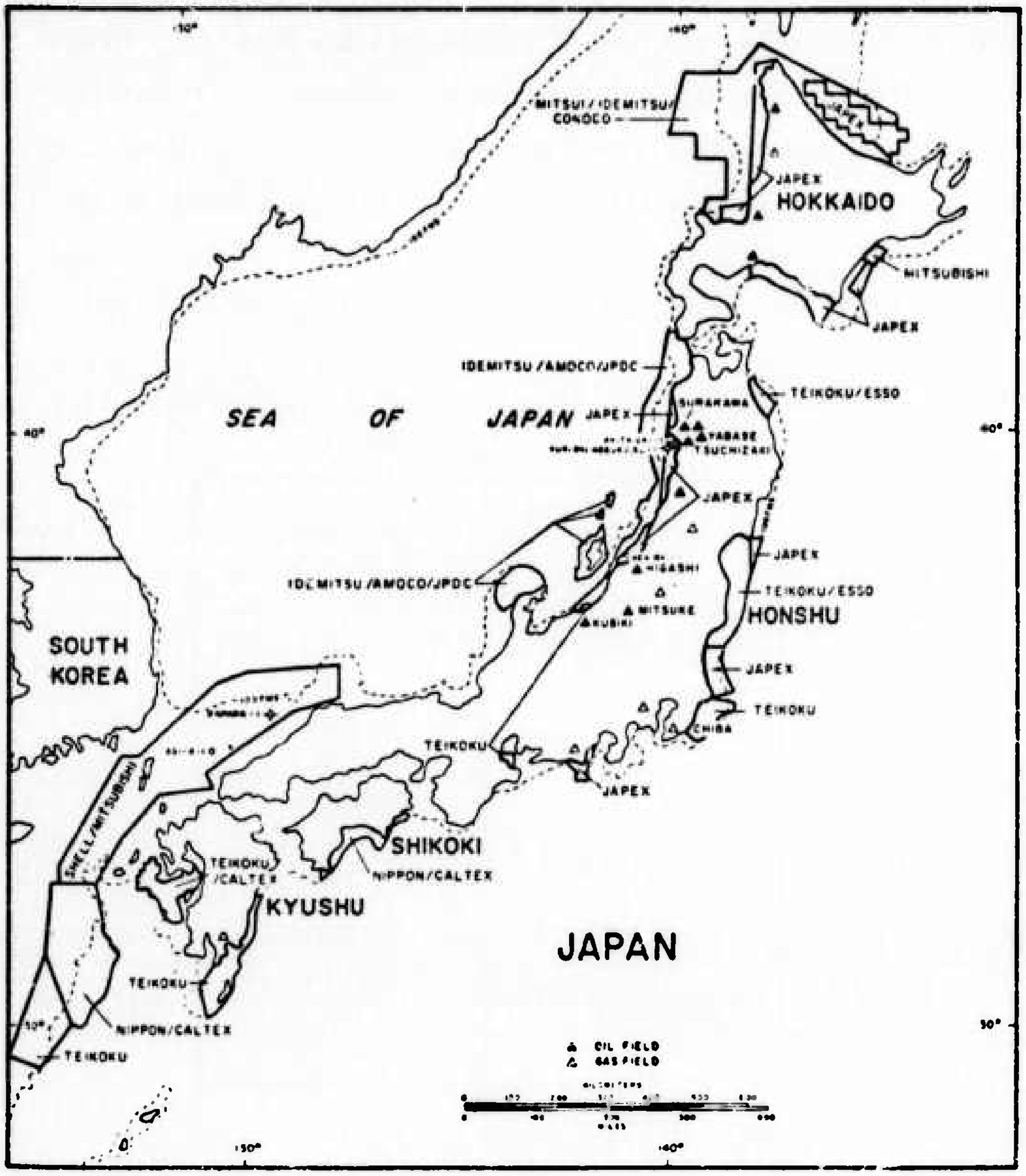
Domestic oil sources were first exploited in Japan in 1867 and many small oil fields have since been discovered over the years (see Figure C. 4).[13] Production is from many small wells, chiefly in the Akita, Yumagata, and Niigata fields, the northwestern coastal Honshu Island, the Azuma field in northern Hokkaido, and the Teshio field of northern Hokkaido. The biggest field is offshore Honshu, discovered in 1934 by directional drilling from land, and from the 130 wells the annual production is only about 135, 000 kiloliters.* Japanese oil production has remained stable for many years (Table C. 3).

Table C.3. Japan: Annual Oil Production 1960-1971

Year	Quantity (10^6 KL)	Energy Equivalent (10^{15} kilocalories)
1960	0.59	.0056
1961	0.82	.0077
1962	0.82	.0077
1963	0.82	.0077
1964	0.70	.0066
1965	0.82	.0077
1966	0.82	.0077
1967	0.82	.0077
1968	0.82	.0077
1969	0.82	.0077
1970	0.94	.0088
1971	0.82	.0077

Source: USGS, 1973 (Reference 15)

* 1 kiloliter = 6. 3 barrels; 10^3 kiloliters/year = 17 barrels/day.



Source· AAPG, 1972.

Figure C.4. Japan: Offshore Concessions and Domestic Oil Fields

Both onshore and offshore geologic, geophysical, and exploratory drilling operations are currently being carried out by Japanese companies jointly with foreign companies as minority partners. The distribution of concessions and exploratory wells for 1971 is shown in Figure C.4.[14] Total reserves are estimated at about 4.6 million kiloliters giving a reserve/production ratio of about 5:1 (Table C.4). There is little indication that domestic supplies will ever make up more than 0.5 percent of total energy needs; potential resources are estimated to be in the 175 to 1750 million kiloliter range including large offshore areas in the Sea of Japan.[15]

Table C.4. Japan: Ratio of Oil Reserves to Production, Selected Years, 1961-1971

Year	Reserves (10^6 KL)	Production (10^6 KL)	Ratio of Reserves to Production
1961	7.697	0.624	12.3
1968	5.600	0.879	6.4
1969	4.300	0.862	5.0
1970	3.995	0.888	4.5
1971	4.056	0.901	4.5

Source: JPI, 1972

C.2.4 Refinery Capacities

Domestic oil refineries in Japan are currently operating at near capacity. This capacity, based on the existing 42 refineries, is given in Table C.5. Projections of increased crude oil use in Japan confirm the need for large increases in capacity. Japan's Petroleum

Table C.5. Japan: Oil Refining Capacity 1971

	Number	Capacity		
		Bbl/day	10^6 kl/yr	10^{15} kcal/yr
Japan sea coast	5	117,560	6.978	0.066
Pacific coast	35	3,956,800	234.876	2.208
Hokkaido area	2	35,000	2.078	0.020
	42	4,109,360	243.932	2.293

Source: JPI, 1972.

Council has recently set annual domestic refining capacity goals for 1975 at about 300×10^6 kiloliters. Assuming that about 90 percent of Japan's crude oil imports will continue to be refined in domestic refineries, this capacity will only barely meet the needs of that year.

Because the Japanese islands are chiefly mountainous and contain little unused land suitable for large industrial complexes such as refineries, any planned increase in domestic refinery capacity will require the development of new siting strategies such as the use of reclaimed offshore land as well as use of more rugged, interior mountainous areas. Refinery sites in Japan are selected as part of a national land use planning activity, carried out by the government.

There are few crude and oil product pipelines in Japan and this reflects the fact that oil consuming industries have limited locations in the environmentally suitable areas near the coast. Movement of oil between such coastal areas is done chiefly by coastal tankers.

Long distance overland transport inland from ports relies heavily on railways. Oil companies and oil transport companies operate more than 7500 tank cars, many of which are 43-ton class. About a third of inland oil movement is by tank trucks. Since the capacity of existing railways is nearly fully used, there have been increasing numbers of schemes to construct pipelines to carry both crude and oil products. The industry in Japan is promoting a billion dollar national pipeline system paralleling existing railways. The first major oil products line, announced in 1972 and scheduled for completion in late 1974, is to run 170 miles from four refineries in the Tokyo Bay area to terminals to the northwest;(16) construction will be through areas of extremely high population density.

Japan is also promoting the construction of refineries in Indonesia, Okinawa, and other Asian countries. This policy, resulting from the shortage of suitable domestic refinery sites and an attempt to reduce air pollution in Japan, also reflects the desire of oil-producing countries to receive tangible technological benefits from their oil trade with Japan. In the future we can expect to see an increasing amount of Japan's petroleum supplies being refined in foreign countries.

C.2.5 Imported Oil

Post-war economic growth of Japan demanded the ready availability of energy sources that could be met economically only by imported crude oil. Financial agreements that were made with foreign oil companies during this early period of post-war growth "tied" Japanese refineries to foreign oil companies so that by 1971, 80 percent of foreign oil was being controlled by international oil companies in which Japan lacked controlling interest.(17) Further, the reliance on imports as well as the geographic distribution of foreign sources paralleled those of Western Europe (Table C. 6). The detailed distribution of imports by country of origin in 1971 is shown in Table C. 7. The result is that Japan is now the world's largest importer of crude oil: nearly 30 percent of the total world movements of crude oil in 1971 were toward Japan, nearly half as much as the total toward all of Western Europe (Table C. 8). A comparison of oil movements from major oil exporting regions to major importing regions shows the prime significance of international oil movements to Japan.

Table C.6. Domestic and Imported Sources of Oil for Major Oil Consuming Areas of the World, 1971

Source	Japan			U.S.			West Europe			USSR		
	Q	E	%	Q	E	%	Q	E	%	Q	E	%
Domestic sources	0.8	0.008	1	567	5.325	65	21	0.197	3	442	4.155	100
Imports (net)	248	2.349	99	310	2.923	35	751	7.059	97	-	-	-
Totals	249	2.357	100	877	8.248	100	772	7.256	100	442	4.155	100

NOTE: Q = Quantity in 10^6 KL; E = Energy Equivalent in 10^{15} kilocalories

Source: IPE, 1972.

C.2.6 Imported Petroleum Products

Although imports of refined petroleum products have fluctuated from year to year, the trend has been upward and is expected to continue to increase. Such increases, however, tend to be overshadowed by the much larger increases in crude oil imports. Imported products, chiefly heavy fuel oil and naptha (Table C. 9) come mainly from refineries in the Middle East and to a lesser extent from the Far East.

Table C.7. Japan: Imports of Crude Oil by Country, 1971

Region and Country	Quantity (10^6 KL)		Energy Equivalent (10^{15} kilocalories)		%
Middle East Total	191.036		1.795		.85
Abu Dhabi		15.190		0.143	.07
Iran		96.423		0.906	.43
Iraq		0.167		0.002	-
Kuwait		20.022		0.188	.09
Neutral Zone		20.696		0.195	.09
Aman		5.748		0.054	.03
Qatar		0.044		-	-
Saudi Arabia		31.025		0.292	.14
Others		1.721		0.015	.01
Far East Total	29.227		0.275		.13
Brunei		2.759		0.026	.01
Indonesia		26.468		0.249	.12
North America — U.S.	0.162	0.162	0.002	0.002	
South America — Venezeula	0.416	0.416	0.004	0.004	
Africa	2.243		0.021	0.021	.01
Cabinda		1.239		0.012	.01
Libya		0.435		0.004	
Nigeria		0.569		0.005	
USSR	0.461	0.461	0.005	0.005	-
Tapped Crude	0.718	0.718	0.007	0.007	
TOTAL	224.263		2.108		100

Source: JPI, 1972.

Table C.8. Pattern of Major World Oil Movements

Exporting Area / Importing Area	Middle East		North Africa		West Africa		Caribbean		Others	
	Q*	%	Q*	%	Q*	%	Q*	%	Q*	%
Western Europe	446	56	192	24	67	8	29	4	69	8
United States	22	10	5	2	6	3	94	42	98	43
Other Western Hemisphere	43	26	10	6	19	12	84	51	7	5
Japan	203	81	2	-	1	-	1	1	44	17
Other Eastern Hemisphere	113	95	-	-	-	-	-	-	6	5
Others	45	70	6	9	-	-	2	3	12	18

* Quantities in 10^6 liters.

Source: U.S. Department of Interior

Table C.9. Japan: Imports of Oil Products, 1971

Country	Heavy Fuel Oil (10^6 kl)	Naptha (10^6 kl)
Bahrein	1.247	0.148
India	-	0.358
Indanesia	3.141	0.243
Iran	1.921	0.315
Kuwait	0.820	1.899
Netherlands	0.222	-
Pakistan	-	0.143
Philippines	0.453	-
Saudi Arabia	1.472	1.227
Singapare	2.120	0.389
Sauth Korea	0.091	0.129
South Yemen	0.735	0.037
United States	1.266	-
USSR	1.173	-
Venezuela	0.240	-
West Indies	0.514	-
Others	0.122	0.142
TOTALS	15.537	5.030

Saurce: JPI, 1972

Imported oil products in 1971 made up less than 10 percent of Japan's total energy supply. This percentage is expected to grow slowly during the rest of the century, although Institute of Energy Economics projections(5) suggest that it may approach 25 percent of Japan's total energy needs by 1985. The projected growth in foreign refining operations reflects the increasing need for Japan to barter technological and developmental assistance to foreign nations in return for favorable oil commitments.

C.2.7 Japanese Government Policy

The central theme of Japanese government energy policy is the security and economic availability of its oil supplies. Japanese control of her oil supply and geographical diversification of her oil sources have become major goals since 80 percent of Japan's oil supplies are from non-Japanese controlled companies, and that more than 85 percent of Japan's crude oil is imported from a restricted geographic area — the Middle East.

As a result of financial agreements made with the major international oil companies during the period of high industrial expansion, Japan became primarily dependent on the major international oil groups and on American independents for its crude oil. These agreements involved loans of nearly $800 million from foreign companies for plant construction and expansion. Terms of these loan agreements require Japan to purchase crude oil in large quantities from foreign oil companies. Such purchases represent a departure from traditional Japanese attitudes which are against large-scale foreign participation in the country's essential industries; present Japanese government policy is aimed at reducing these agreements.

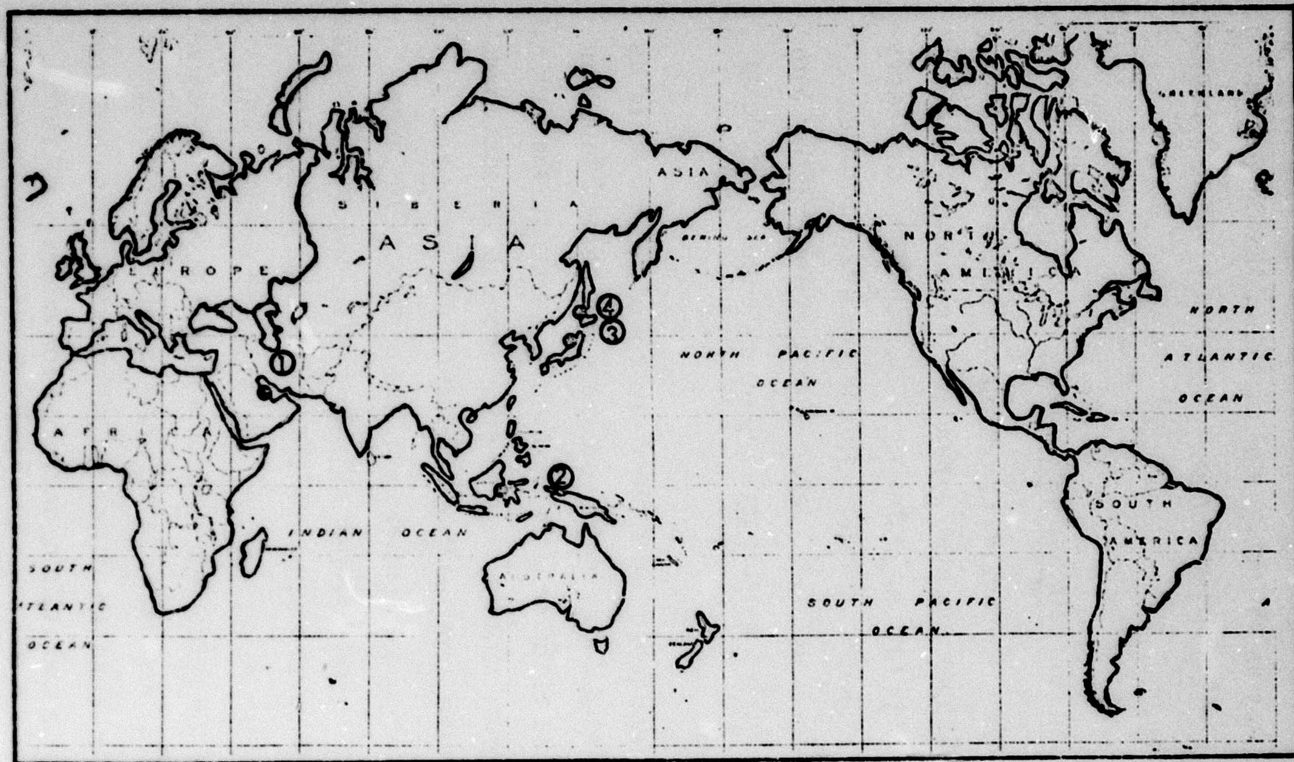
The Japanese government is vigorously promoting the exploration and development of foreign oil resources by companies in which Japanese capital and control are predominant in order to free both crude oil supplies and marketing and refining operations from foreign control. Interests of Japanese oil companies are fostered through low-interest loans, strong administrative guidance from the government, and elaborate regulations of foreign oil companies operating in Japan. The fact that Japanese oil companies are exploring and/or producing oil in more than a dozen countries of the world results directly from the government policy. By 1985, it is estimated(18) that Japanese companies will be in as many as 45 foreign countries and that 30 percent of Japan's oil needs will be supplied through companies in which Japanese interest predominates.

C.3 Japan's Search for New Sources of Oil

In vigorous efforts to achieve geographic and political decentralization of energy supply sources, Japanese oil companies — commonly in partnership with foreign state-owned companies — are carrying out active oil development or exploration in more than a dozen countries of the world. In addition, Japan is actively negotiating with a number of other countries which currently do not supply significant amounts of oil to Japan.

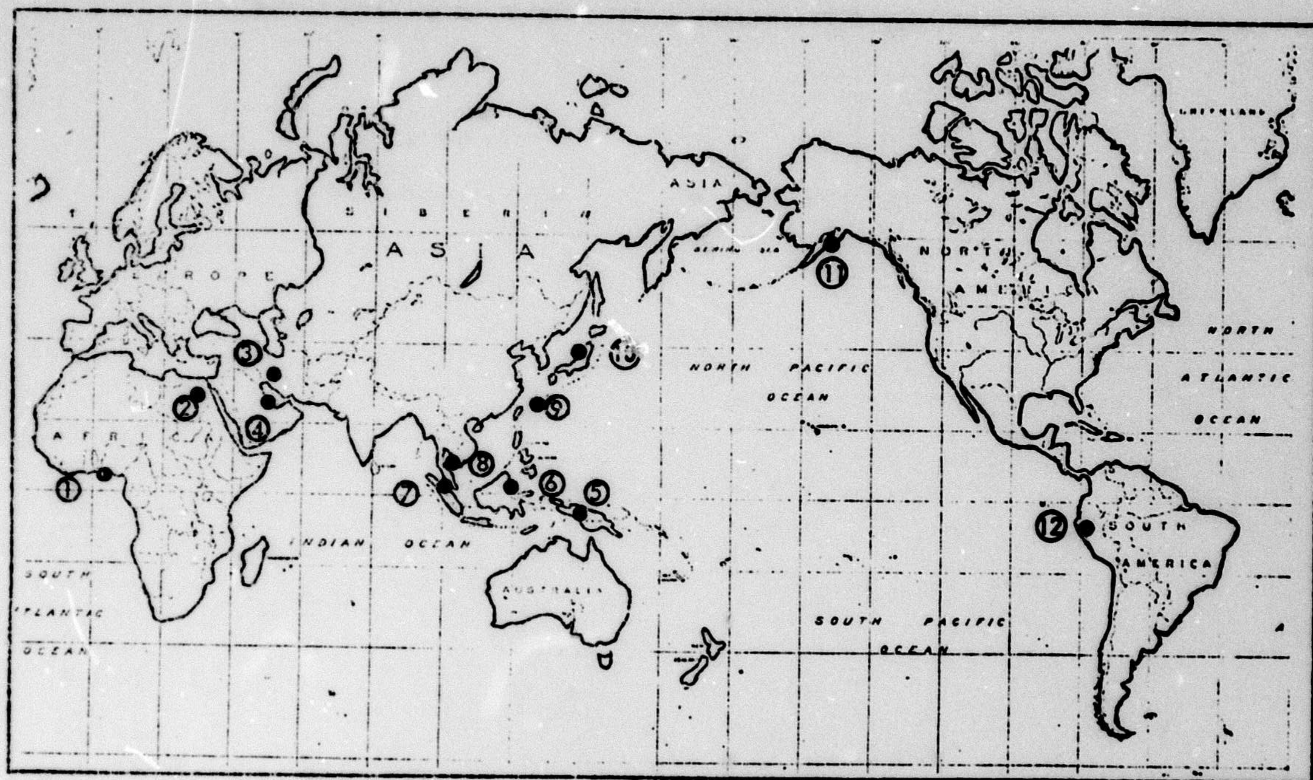
Japan's current goal is to achieve control of 30 percent of its foreign oil supply by 1985; it currently controls only about 20 percent (Figure C.5). Because of the economics of oil exploration, the bulk of Japanese controlled oil will continue to come from the Middle East in 1985. Only during the latter part of the century are significant changes expected in the overall patterns of oil movements to Japan. By then, if Japan's plans and policies are successful, the greater part of Japan's foreign oil sources will have shifted from the Middle East to the Far East and other Asian sources. Japanese companies will have a large share of the petroleum development and processing activities in many countries, and Japan is expected to achieve technological prominence in such fields as deepwater petroleum exploration and production and in pipelining and refining facilities for offshore oil fields.

Summaries of Japan's foreign oil activities are given below. Their locations are shown in Figures C.6 and C.7.



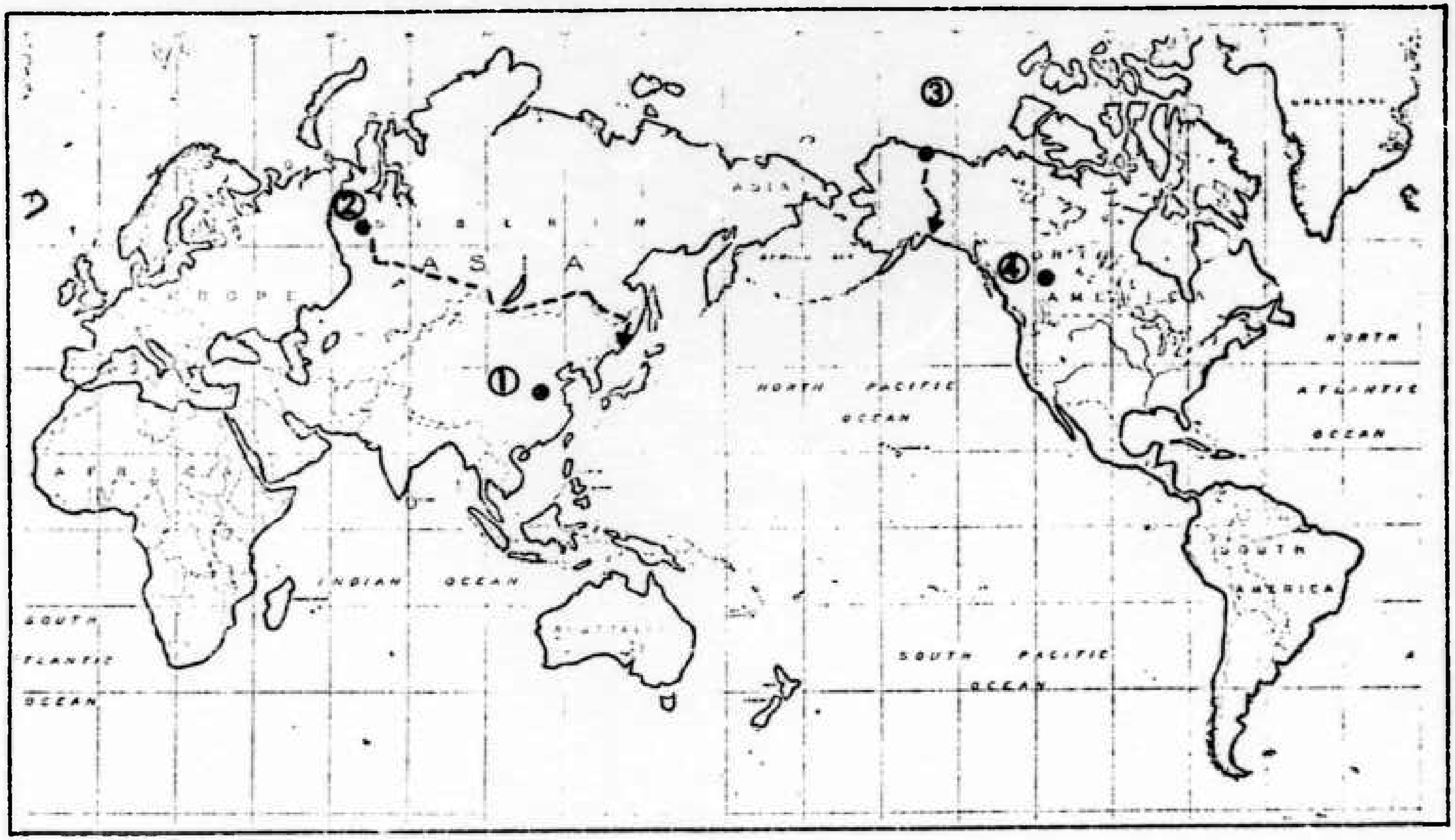
① Abu Dhabi; Kuwait-Saudi Arabia Neutral Zone
② Kalimantan, Indonesia
③ Honshu Island
④ Hokkaido Island

Figure C.5. Areas in which Japanese-Controlled Companies Supply Oil to Japan



1	Nigeria	5	New Guinea	9	Okinawa
2	Egypt	6	Indonesia	10	Offshore Japan
3	Iran	7	Sumatra	11	Alaska
4	Abu Dhabi; Qatar	8	Thailand	12	Peru

Figure C.6. Areas of Japanese Oil Exploration Activities



① Peoples Republic of China
② West Siberia
③ North Slope, Alaska
④ Athabaska tar sands

— — → Proposed pipelines

Figure C.7. Areas of Japanese Interest in Foreign Oil Sources

C.3.1 Abu Dhabi

Abu Dhabi represents Japan's most successful effort to obtain control of substantial foreign oil production. The Abu Dhabi Oil Company, a consortium of Japanese companies, made a major discovery in 1969 in the Mubarras field offshore Abu Dhabi (Figure C.8). Reserves of this field are estimated at about 300 million kiloliters and production in 1972 had reached an annual rate of around three million kl.[13] Production is expected to double by 1975 and to eventually reach 12 million kl per year. The company continues to make vigorous geophysical and exploratory drilling efforts offshore.

C.3.2 Alaska

Ever since the initial discoveries of oil on Alaska's North Slope (Figure C.9), Japan has shown great interest in the estimated nine billion barrel reserves.[19] A trans-Alaskan pipeline, terminating at a port in southern Alaska, would make North Slope oil readily available for tanker shipment to Japan. The projected inability of the U.S. West Coast to absorb all output from such a pipeline, has caused Japan to frequently be cited as a logical market, at least temporarily, for the excess oil;[20] Japan has frequently expressed official interest in obtaining some of this oil. The oil companies say that any shipments to Japan would be small and only for a short time; critics of the trans-Alaska pipeline, however, believe that Japan might be the market for a substantial amount of North Slope oil if the pipeline is constructed.[21] In any case, legislation is currently pending before the U.S. Congress that would prohibit the export of any North Slope oil. It is not believed that the oil will reach any markets before the late 1970s. The Japanese North Slope Petroleum Company was formed in 1970 to carry out oil

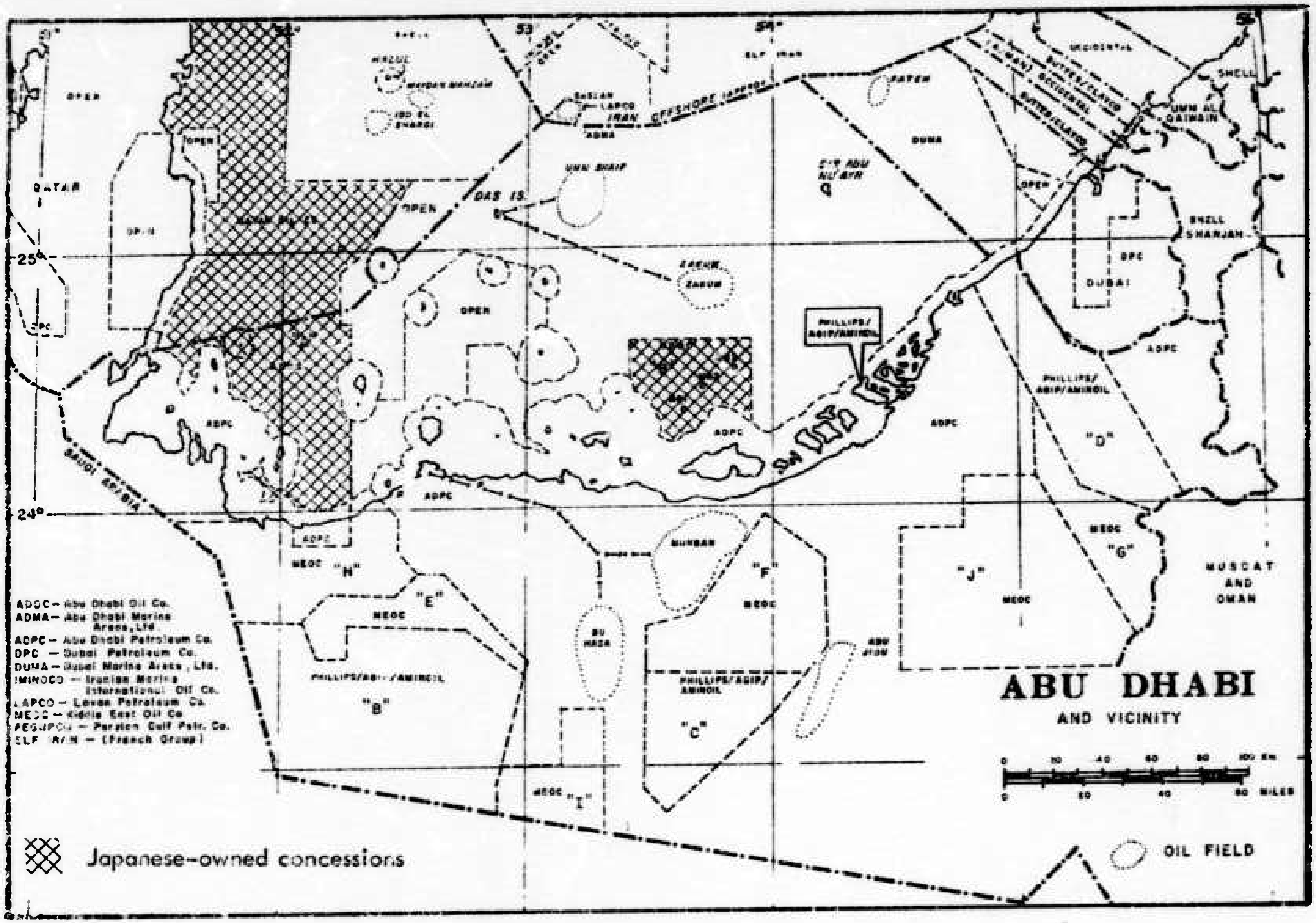
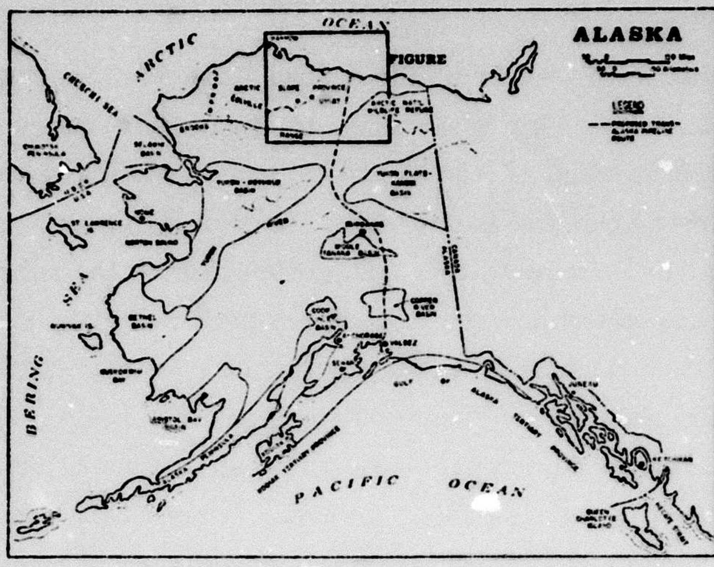
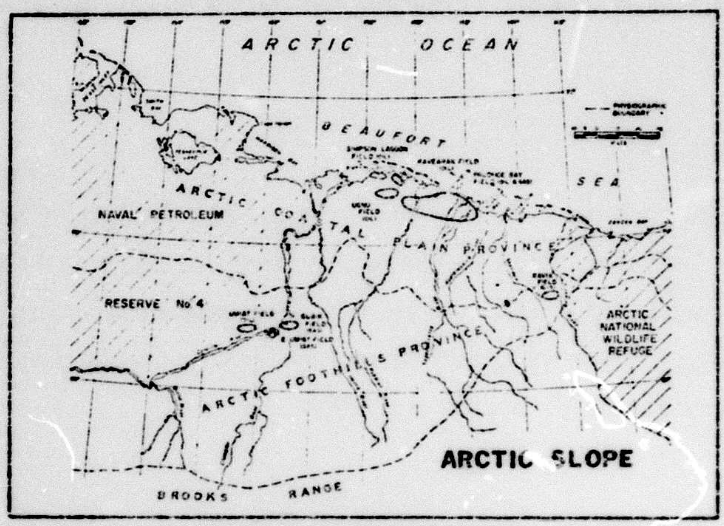


Figure C.8. Japanese Oil Concessions in Abu Dhabi and Vicinity



a. Alaskan Major Sedimentary Basins



b. North Slope Oil Fields

Source: AAPG, 1972

Figure C.9. Alaskan Oil and Gas Provinces exploration in northern Alaska; this company has since abandoned all efforts in Alaska.

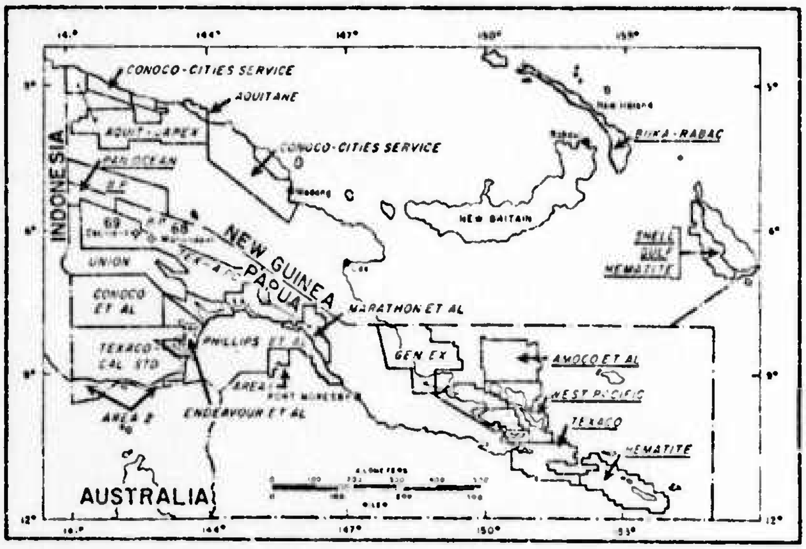
Another Japanese firm, the Alaska Petroleum Development Company, is in partnership with a U.S. oil company to carry out geophysical work in the Gulf of Alaska, which has substantial potential resources of petroleum but is currently not opened to development or drilling. Offshore leasing by the U.S. government in the near future is uncertain; opposition to such leasing has been raised by the state of Alaska. Should the trans-Alaska pipeline be constructed to a southern Alaska port and should later exploration prove large reserves in the Gulf of Alaska, U.S. oil companies may feel strong incentives to market the excess oil to Japan. This, however, is not likely because of the growing shortage of U.S. domestic oil sources which makes it improbable that U.S. policy would permit the export of any domestic oil.

C.3.3 Australia

JAPEX Australia jointly holds an oil concession in Northwestern New Guinea (Figure C.10) in which exploratory activity has been carried out for the past two years. Protests by Australian environmental groups, however, has forced JAPEX to suspend exploratory drilling and to search for new areas.[22]

C.3.4 Canada

The development of the Athabaska tar sands in Alberta (Figure C.11) has figured prominently in Japan's plans to increase its diversification of oil imports in the future.[23] The tar sands of Alberta represent one of the world's two largest reserves of nonconventional

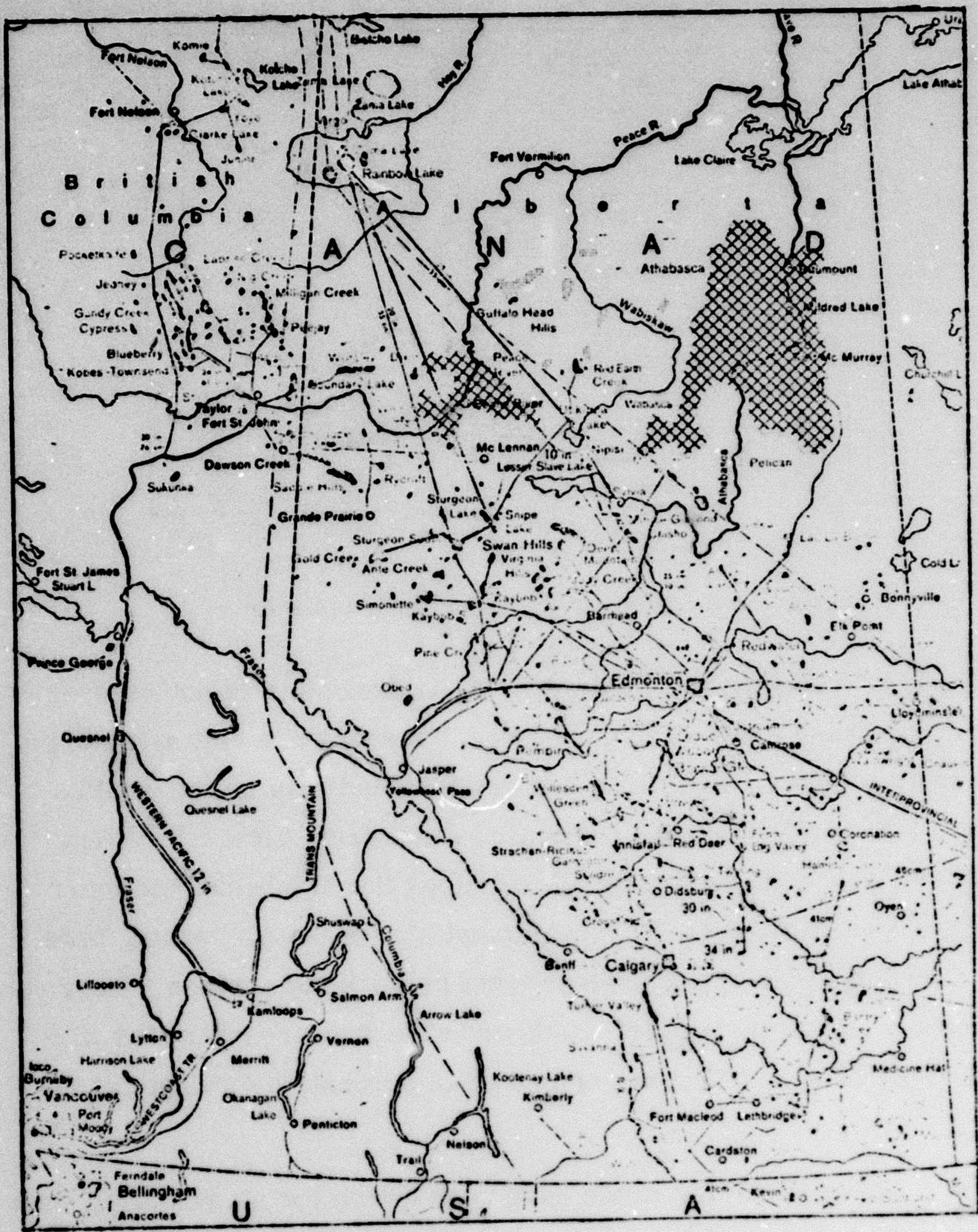


Source: AAPG, 1972.

Figure C.10. Japanese oil Concessions in Australia

oil deposits (deposits in which oil in its natural state is not recoverable by ordinary production methods). Reserves are estimated to be as large as those of U.S. oil shale deposits and may be the world's largest known oil reserve. Estimates range from 50 to 60 trillion kiloliters.(24) The deposits crop out along the Athabaska and other rivers of central Alberta(25) but in most places the oil bearing beds lie a few hundred to a few thousand feet beneath the surface. They consist chiefly of unconsolidated sands and silts that are saturated with highly viscous oil that makes up two to 10 percent, by weight, of the total.(24)

Although the tar sands have been known for many years, technical limitations and governmental restrictions have prevented large-scale development. Research and development on recovery methods have included strip mining of the shallower deposits; steam and hot water flooding by well systems of deeper beds; and burning in place. Currently one small plant is producing about 2.67 million kiloliters of



Principal areas of tar sands

Figure C.11. Western Canadian Oil and Gas Fields, Pipelines, and Tar Sands

of crude oil by processing strip-mined sands. Increases in production, which are expected to begin in 1973, are based on strip mining operations rather than on any in situ recovery techniques. The provincial government of Alberta has just begun to review economic and other factors bearing on long-range policy for the development of the tar sands.[26]

Without considering environmental costs, several aspects of exploration and development of the tar sands are much cheaper than that for conventional oil fields. The deposits are well delineated and their occurrence is so well understood that exploration costs are relatively small. Further, tested recovery methods show an efficiency of 75 percent or more, far more than the 35 percent for recovery of oil in conventional fields.

As evidence of their interest in Alberta tar sands as a potential source of imports, Japan sent a mission to Alberta in April 1973 to discuss these sources. No agreements or negotiations have been announced, and it is probable that Japan would face some formidable North American environmental and economic concerns over development of the tar sands. Because the tar sands represent a potential future source of oil for the midwestern and eastern markets in the United States, this country may take a dim view of any Canadian-Japanese deal to export oil that could be readily pipelined to midcontinent United States.

Similarly, Canada may be reluctant to face the environmental problems associated with the production, transportation, and marine shipment of tar-sand oil for the benefit of a foreign consumer. Environmental problems already recognized include disposal of enormous quantities of sand spoil generated by large-scale strip mining operations;

the consumption and disposal of large amounts of heat and water involved in in situ recovery methods entailing hot water and steam flooding; and the disposal of the high sulfur content of the oil. Additional environmental and transportation problems would be related to pipelining the oil to the Puget Sound area and subsequent oil tanker operations.

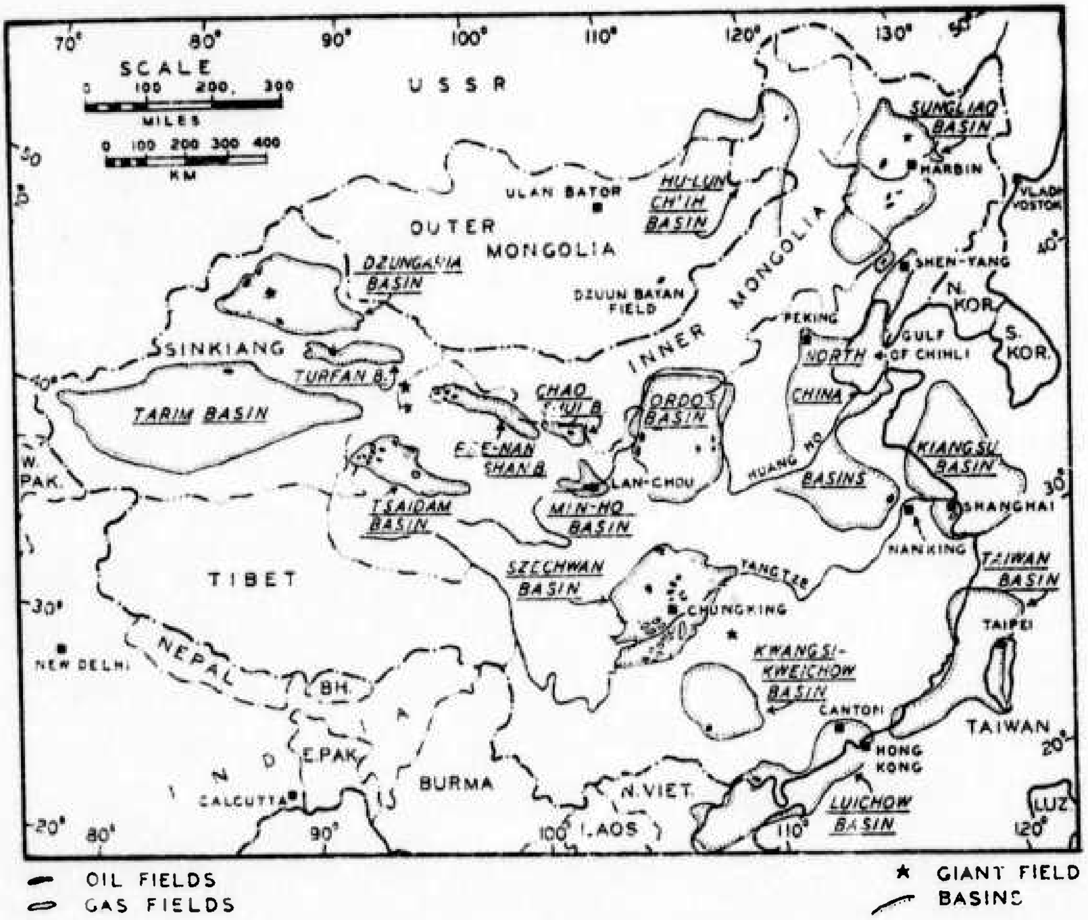
Although Japan openly considers Alberta tar sands as an important potential source for future imports, the environmental, technical and North American energy policy considerations make it an unlikely source during this century. JAPEX Canda, the Japanese exploration company, has also carried out geophysical surveys in Saskatchewan and exploratory drilling in Alberta, but with no success.

C.3.5 China, Peoples Republic (PRC)

The Peoples Republic of China is currently self-sufficient in domestic oil resources.[27] Oil production in 1971 was about 30 million kiloliters with proved reserves estimated at about 3000 million kiloliters, a ratio of production to reserves of 1:100.[15]

The Japanese, therefore, have recently been looking to PRC for a portion of its oil production as well as concessions for oil exploration and development within mainland China (see Figure C.12).[28] Recently an agreement was negotiated that would provide for delivery of as much as 3.5 million kiloliters of crude oil from China's large Taching field beginning in 1974.[29, 30]

In 1972, PRC was reported to have asked Japanese companies to design a 745-mile pipeline that would bring crude oil to the coast from inland fields to permit export by tanker. Although PRC has agreed to sell oil to Japan, a Japanese trade delegation to PRC reported early



Source: AAPG, 1970.

Figure C.12. Oil Basins of Peoples Republic of China

this year that Chou En-Lai does not intend to permit any foreign participation in its oil and gas exploration or development.[31] More recent reports, however, indicate that several American oil and equipment companies have been invited by PRC to discuss assistance in developing offshore areas, and suggest that China's previous declarations applied specifically to Japan rather than to other foreign countries. Further, there has been speculation that Japan may have been a silent partner having direct interests with American companies negotiating with PRC.[32]

C.3.6 Indonesia

Japanese efforts to develop control over its own sources of oil have met with moderate success in Indonesia. During the past ten years, Japan's North Sumatra Oil Development Corporation (NOSODECO) has drilled several hundred producing wells in the Rantan, Paluh Tabuhan, and Tandjungpura fields (Figure C.13). NOSODECO has provided equipment and technological assistance to Pertamina, the Indonesian state-owned oil company, in return for which Japan received a portion of oil production. Exploration continues in these fields.

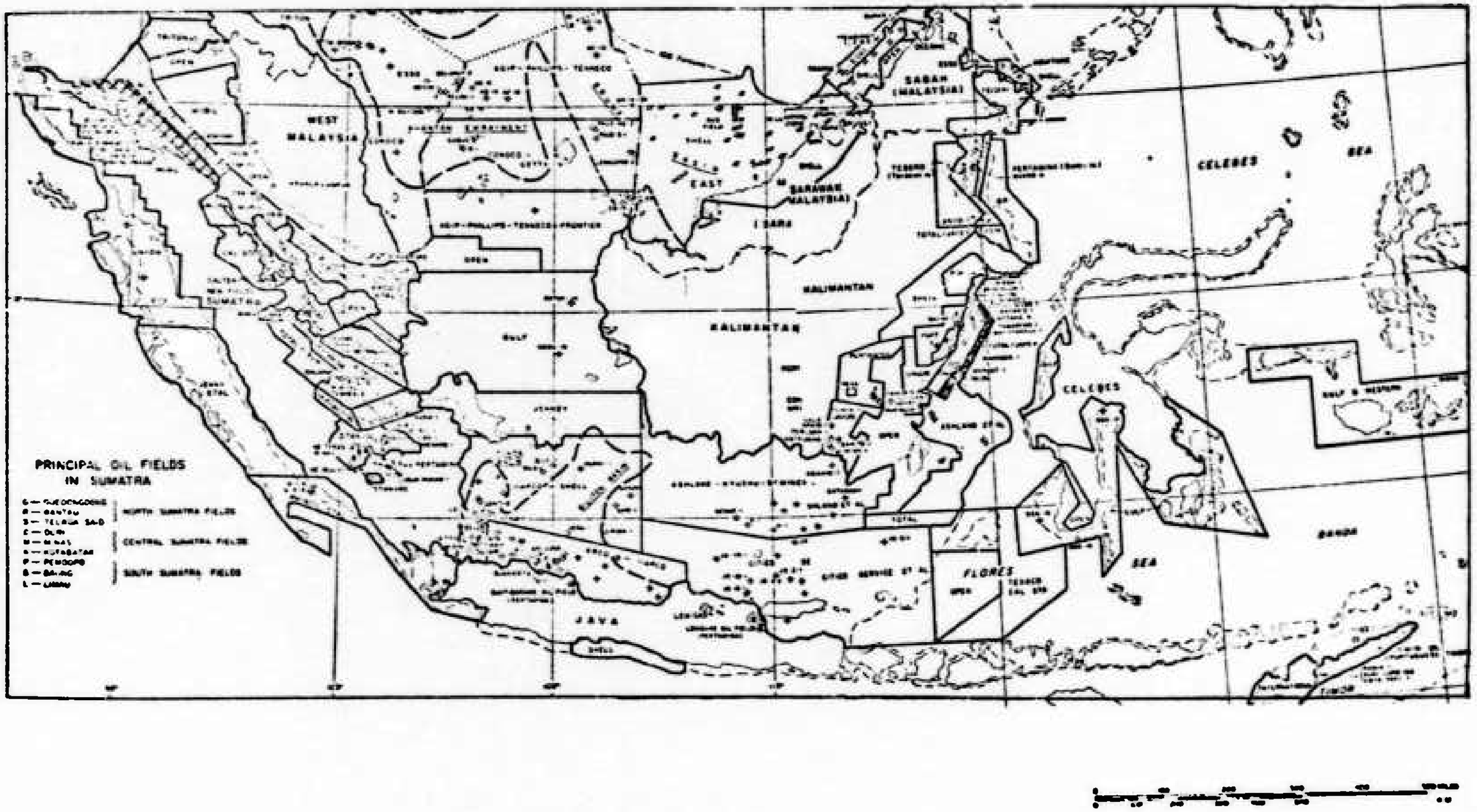
JAPEX, in partnership with Union Oil of California, is developing the Attaka field offshore eastern Kalimantan. Current production is about 4.4 million kiloliters and is expected to rise to almost 6 million kiloliters in 1973.[13] Attaka is reported to be the largest single offshore oil field yet discovered in Indonesia.

Another Japanese consortium, the Japan-Indonesian Oil Company, recently signed an agreement with Pertamina to receive nearly 6 million kiloliters per year of crude oil, partly in return for developmental loans and credits extended by Japan.[33]

Indonesian oil has extremely low sulfur content (0.1 percent) which is especially attractive to Japan who needs an environmentally acceptable fuel. Japan has provided more developmental loans in Indonesia than in any other Asian country.[34]

C.3.7 Iran

In mid-1971, Japan received her first oil concession in Iran when a group of Japanese companies formed the Iranian Petroleum Corporation and were awarded exploration grants to tracts in the promising Lurestan region west of Kermanshah.[13] It shares interest in



Source: AAPG, 1972.

Japanese concession areas

Figure C.13. Southwest Pacific Area, Oil Concessions, 1971 the area with Mobil Oil and the government-owned National Iranian Oil Company. Geological investigations have continued for the past year.

C.3.8 Egypt

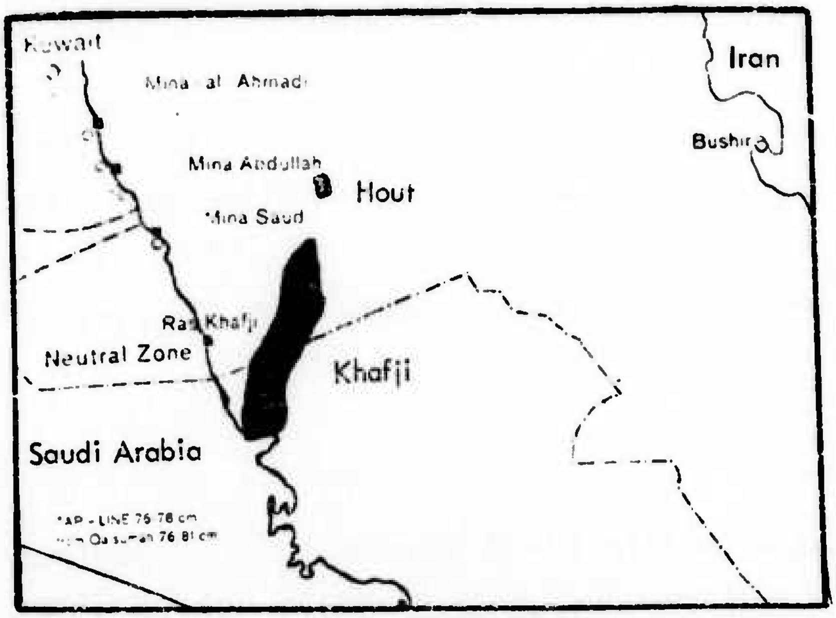
The Japanese North Sumatra Oil Development Corporation had a drilling program underway in 1971 in a small concession in the Gulf of Suez. No success has been reported.

C.3.9 Kuwait/Saudi Arabia/Neutral Zone

The Japanese Arabian Oil Company (AOC) has been producing oil from the offshore Khafjii and Hout oil fields since 1961 (Figure C.14). In 1971, production was about 20 million kiloliters. Although production has declined somewhat in recent years, crude oil reserves are estimated at nearly 4 billion kiloliters and exploratory drilling continues. The AOC owns and operates a 1.8 million kiloliter (30,000 b/d) refinery at the coastal terminal that is connected by a 30 million kiloliter (500,000 b/d) pipeline with the offshore fields.[13]

C.3.10 Nigeria

The Japan Petroleum Corporation shares exploration concessions on shore with American, West German, and Nigerian firms.[35] Exploratory drilling in offshore leases have met with some success although no production has begun.[36]



Source: IPE, 1972. Oil-Producing Nations

Figure C.14. Areas of Japanese Oil Production in Kuwait/ Saudi Arabia and Neutral Zone

C.3.11 Okinawa

When the Ryukyu Islands reverted to Japan in May 1972, there was a reorganization of the existing oil companies on Okinawa to provide for Japanese priorities in the existing international companies that had been operating there during the U.S. administration. No oil has yet been discovered in the Ryukyus, but several seismic surveys have been made that suggest that the island may have a good oil potential.

C.3.12 Peru

Japan's Andes Oil Company reached an agreement with Peru early in 1973 for a 4000 square mile exploration concession in the upper

Amazon basin.[37] Any discoveries made in the area would require pipeline construction to reach Pacific ports.

C.3.13 Qatar

The Qatar Oil Company, composed of seventeen Japanese companies, has a 3000 square mile concession offshore that has had promising tests and from which substantial production is expected (Figure C.8).

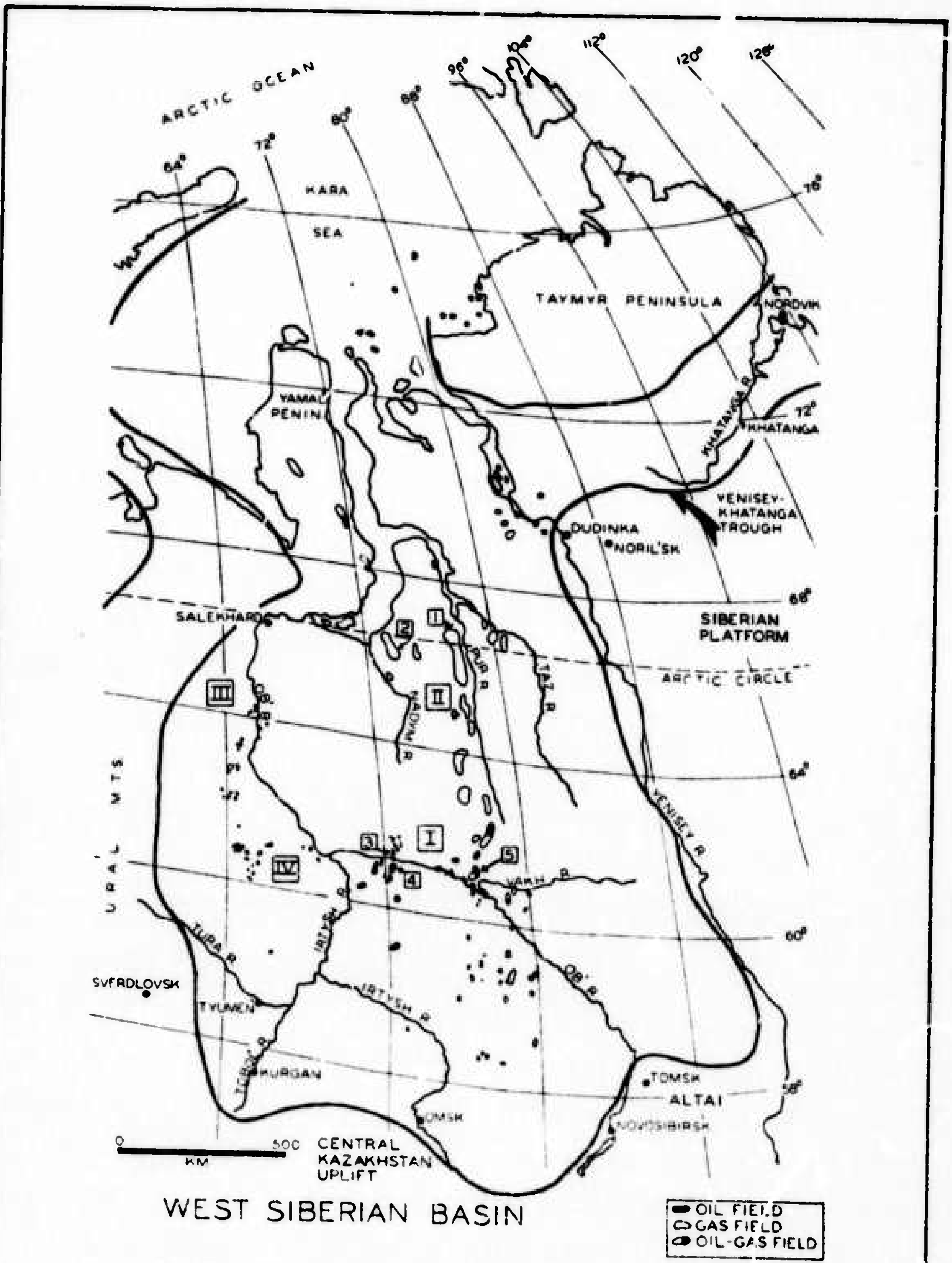
C.3.13 Thailand

Several Japanese groups are partners with several foreign companies in onshore and offshore exploration leases in southern Thailand (Figure C.13). No oil discoveries have been made yet in the Gulf of Thailand, although promising tests have recently been reported.[38]

C.3.14 USSR

Western Siberia is forecast to become the principal oil-producing area of the USSR by 1975 and to continue as such at least until the year 2000. Within the past dozen years, a cluster of giant oil fields has been discovered in the West Siberian Basin around the middle portion of the Ob River in Tyumen Province (Figure C.15).[39]

Shortage of pipeline capacity and lack of adequate rail and highway networks have been the main constraints on oil production, but construction of large pipelines to the east as well as to the west is rapidly easing this constraint. Portions of a trans-Siberian pipeline system from the Ob River oil fields are currently under construction: 500 miles of 48-inch trunk line were completed in early 1972, and construction of pipeline and associated refineries are currently underway



West Siberian basin. (1) Urengoy field; (2) Medvezh'ye field; (3) Ust'-Balyk field; (4) Mamontovo field; (5) Samotlor field. I = Middle Ob' oil province; II = Pur-Taz gas province; III = Berezovo gas provinces; IV = Shaim oil province.

Source: AAPG, 1972.

Figure C.15. Oil and Gas Fields of West Siberia as far east as Irkutsk, near Lake Baikal. The extension of pipeline eastward to the port of Nakhodka on the Sea of Japan is in an advanced planning stage; the Bechtel Corporation (U.S.) is reported to be providing technical assistance to the USSR government.[40]

No completion date has been announced, but such a trans-Siberian pipeline would make West Siberian oil readily available to Japan (as well as to west coast United States); Japan, therefore, has shown strong interest in participating in the project. West Siberian production has been forecast to rise from 140 million kiloliters in 1975 to 270 million kiloliters in 1980 to nearly 600 million kiloliters by the year 2000.[41] This makes West Siberia capable of becoming a major future supplier of oil to Japan. Japan has expressed a desire to obtain about 60 million kl of crude oil per year ($.564 \times 10^{15}$ kcal) which USSR has reported as possible by 1975.[42] If this were reached, it would mean that more than 40 percent of the anticipated production of the West Siberian fields would be going to Japan,[40] and that these fields would be supplying more than 15 percent of Japan's total energy needs by that time. A potential drawback to pollution-conscious Japan, however, is the relatively high sulfur content of West Siberian oil.[13]

A projection of this same percentage to the year 2000 shows Japan receiving more than 200 million kl per year (2.23×10^{15} kcal) or more than 20 percent of her estimated energy needs. Presumably by this time USSR domestic requirements as well as those of other foreign markets will have increased to a point that reducing Japan's share of this oil, but still West Siberia has the capability of being an important element in Japan's new energy sources during the next 25 years.

The long standing dispute between USSR and Japan over the Habomai Islands, four small islands north of Hokkaido, is not expected to affect negotiations between these countries for Siberian oil.

C.3.15 Black Sea Oil

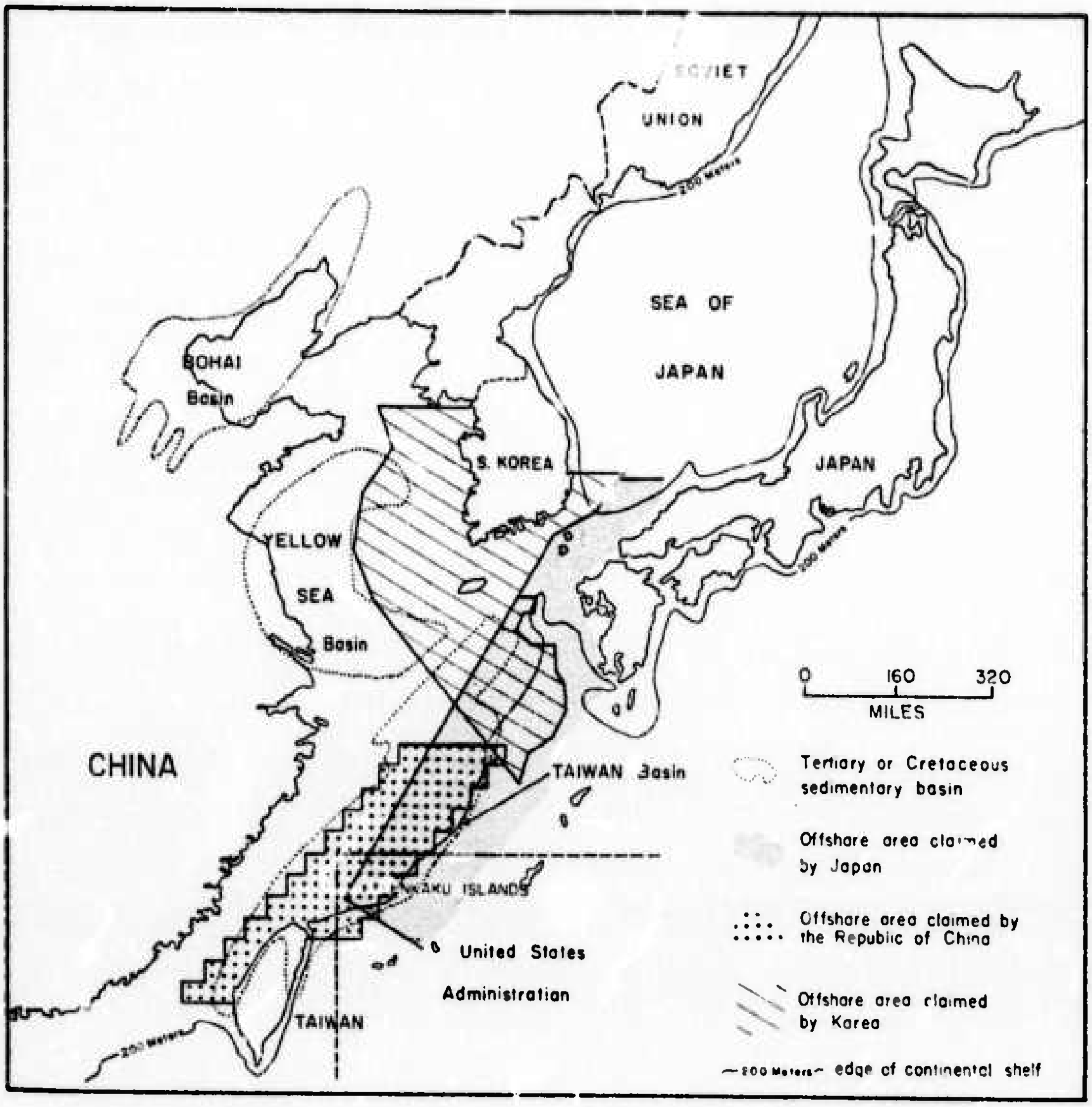
Japanese imports of crude oil from Russian Black Sea ports were cut off by the closing of the Suez Canal in 1967. The loss was covered, however, by an international cooperative agreement whereby the Soviet oil to Japan was replaced by oil from Iraq and Iraq's West European markets in turn received equivalent amounts of Soviet oil. In effect, this obviated the need for oil transport through Suez to Japan and made more efficient the transportation of oil from Middle East sources to Far East markets.

C.4 Potential Political Problems Associated with Japan's Search for Oil

C.4.1 Eastern Asia

Reconnaissance surveys in 1969 suggest that large potential oil resources may exist on the continental shelf in the Yellow Sea and the China Sea.[43] On the basis of preliminary geologic and geophysical data, it has been estimated[44] that potential reserves of this area may be comparable to those of the Persian Gulf area (i.e., in the range of 17 to 175 billion kl).[15] Discoveries of oil in coastal areas of Peoples Republic of China (PRC) support further these estimates of a high potential for the offshore areas.

Based on the preliminary surveys, Japan, Nationalist China, and South Korea have independently granted exploration concessions in these offshore areas to various foreign companies. Because of the irregularity of coastal configurations, the distribution of a large number of islands in the area, and the ambiguities of international law, the offshore claims by these three countries overlap[45] (Figure C.16) and have been the subject of disputes that have become increased in significance as has the interest in oil exploration of the area.



Source: AAG, 1971.

Figure C.16. Prospective Oil Fields and Disputed Areas in Eastern Asia

Boundary disputes first occurred in 1970 when South Korea granted a concession to Wendell Phillips to explore in the Korea Strait and the East China Sea. This concession overlapped an area claimed by Japan where several international companies in which Japanese firms had interests were seeking concessions from Japan.[46] Early in 1973, South Korea and Japan reached an agreement on territorial boundaries in the Korea Strait and on joint exploration for oil in a 234,000 square mile area of the East China Sea south of the strait.[47] Nationalist China bases extensive offshore territorial claims in the East China Sea on its claim of sovereignty over the Senkaku Islands. On the basis of this claim, Nationalist China has granted permits for exploration over much of the continental shelf surrounding the Senkakus. In addition, following the reversion of the Ryukyus to Japan, Japan has also claimed the Senkakus.

PRC has not yet been involved in offshore concessions but may represent a source of future conflict regardless of the resolution of the conflicts among the other three countries. Taiwan had granted several exploration concessions for seismic work in the East China Sea. In 1971, however, seismic work was halted after PRC announced its claim to offshore waters around Taiwan and the Senkakus and the U.S. State Department told Taiwan that the U.S. could not intervene if seismic ships were seized by PRC. PRC, in addition, has objected to the settlement of the Japan-South Korea boundary in the Korean Strait, citing its territorial claim to waters 200 miles offshore, based partly on its claim of sovereignty over such offshore islands as Taiwan and the Senkakus.

Because of PRC's unresponsiveness to Japanese interests in exploration and development for oil in mainland China, it is expected that Japan might support the claims of countries other than PRC in potential offshore oil areas of the Yellow and China seas.

C.4.2 Japanese Northern Islands

The Habomai Retto, four small islands off the northern coast of Hokkaido, have been the subject of territorial dispute between USSR and Japan for the past 25 years. These four islands had been traditionally part of "mainland" Japan but were occupied by USSR after World War II and are claimed as Soviet territory. Currently, the disposition of acquisition of the Kurile Islands and these islands is a major obstruction to the signing of a Russian-Japanese peace treaty. The Soviet Union offered a compromise but it is a strong nationalistic issue to Japan and there are no indications that Japan would accept anything less than all of her former territory.[48]

Current Japanese oil exploration activities extend around parts of the northern coast of Hokkaido (Figure C.17) but do not reach the disputed islands. The islands lie within the East Asian continental shelf and in the future may give rise to critical claims for territorial offshore waters and escalate the dispute far above the current issues based on national pride and national defense.

C.4.3 Gulf of Thailand

Conflicting territorial claims for areas of potential oil resources in the Gulf of Thailand (Figure C.18) create the possibility of more serious future conflicts when oil discoveries are made. The offshore continental shelf areas bordering Thailand, Cambodia, and South Viet Nam have large potential oil and gas resources, estimated to be in the range of a few hundred million to more than a billion kiloliters,[15] although there is currently no petroleum production nor have any discoveries been made. This potential has attracted the interest of Japanese oil groups as well as other international oil companies.[49]

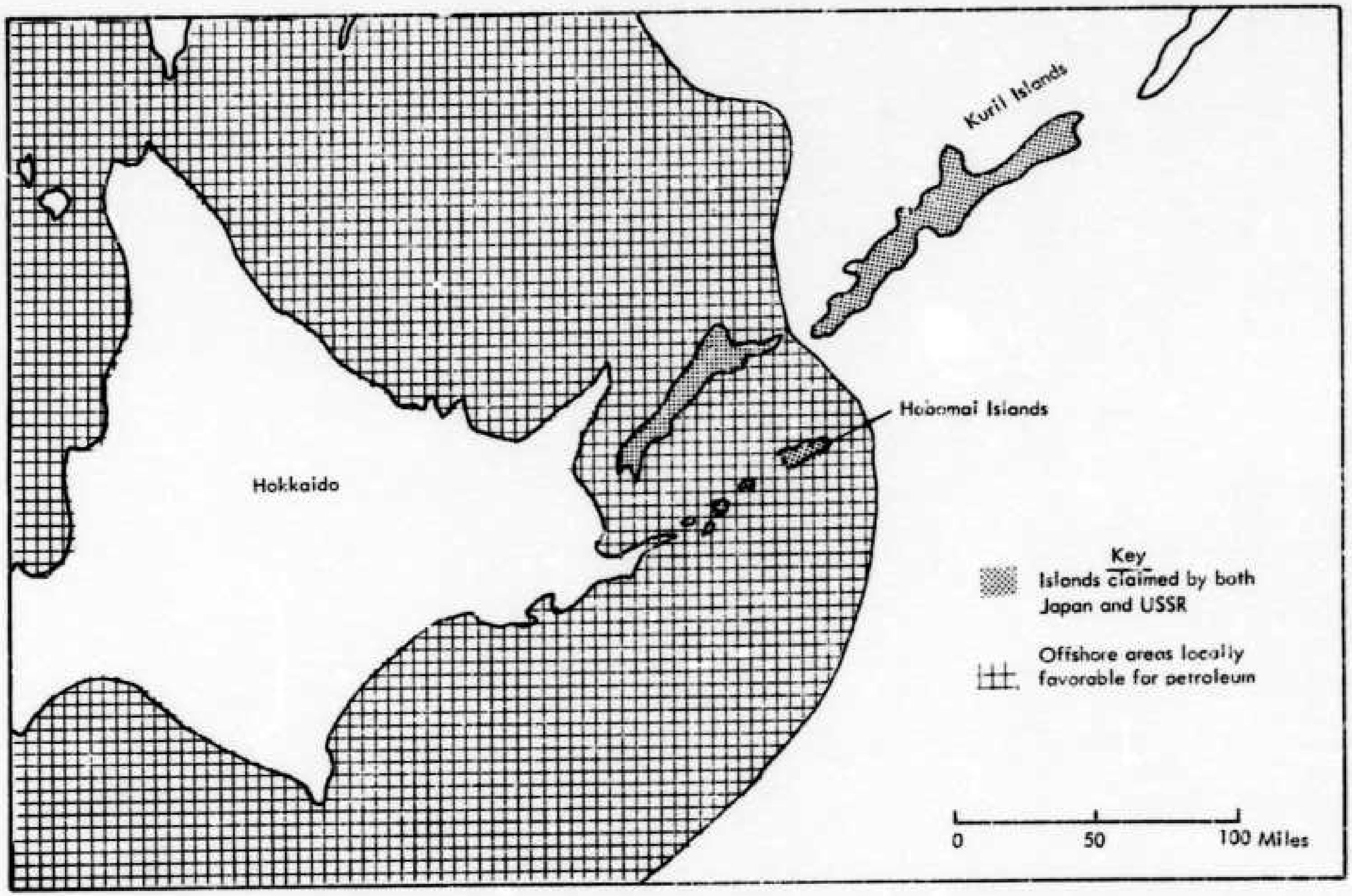
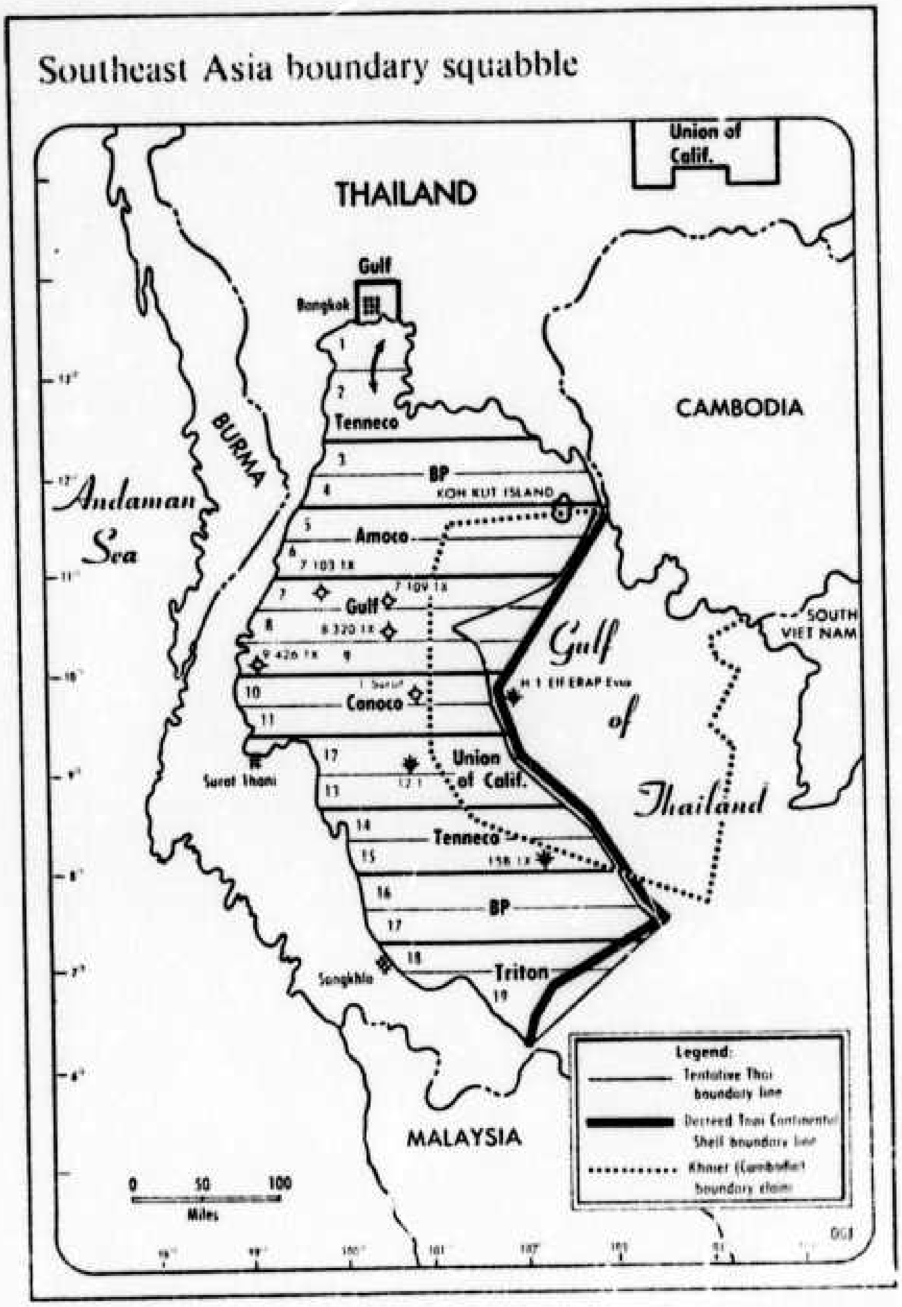


Figure C.17. Japanese Northern Islands



Source: Oil and Gas Journal, July 9, 1973

Figure C.18. Gulf of Thailand, Prospective Oil Basin and Disputed Areas

Thailand has awarded exploration licenses to a number of foreign oil companies, including two Japanese groups, for the entire Gulf of Thailand.[13] Cambodia had previously granted offshore exploration concessions to a French company in the eastern portion of the Gulf of about 15,000 square miles, much of which has since been relinquished. About 4,000 square miles of the area claimed by Cambodia, however, overlaps Thailand offshore claims. In addition, South Viet Nam offshore claims overlap about 20,000 square miles of Cambodian claims. Cambodia is preparing to open its offshore areas for international exploration bids; South Viet Nam has not yet granted any exploration concessions, but bids for offshore concessions have recently been received from major oil companies of six countries, including Japan.[50]

Offshore jurisdiction between Cambodia, Malaysia, and Indonesia also remains unsettled and is a source of potential future conflict as the oil potential of these regions becomes better known. Although there is no evidence that Japanese companies have been seriously involved in such territorial disputes, Japan's position in the future can be expected to be strongly governed by her consideration of the area as a future energy source.

C.4.4 The Malacca Strait

The Malacca Strait, a narrow, relatively shallow channel lying between Malaysia and Sumatra (Figure C.19), has become an important oil tanker route between the Middle East and Japan. Malaysia and Indonesia both claim a twelve-mile limit for offshore territorial waters and therefore both claim a portion of the entire width of the Malacca Strait.[51] The two nations are seeking to exercise joint control over shipping in the Strait. During the past year or so they have been seeking international support, chiefly from the so-called "non-aligned" nations, to ban tankers

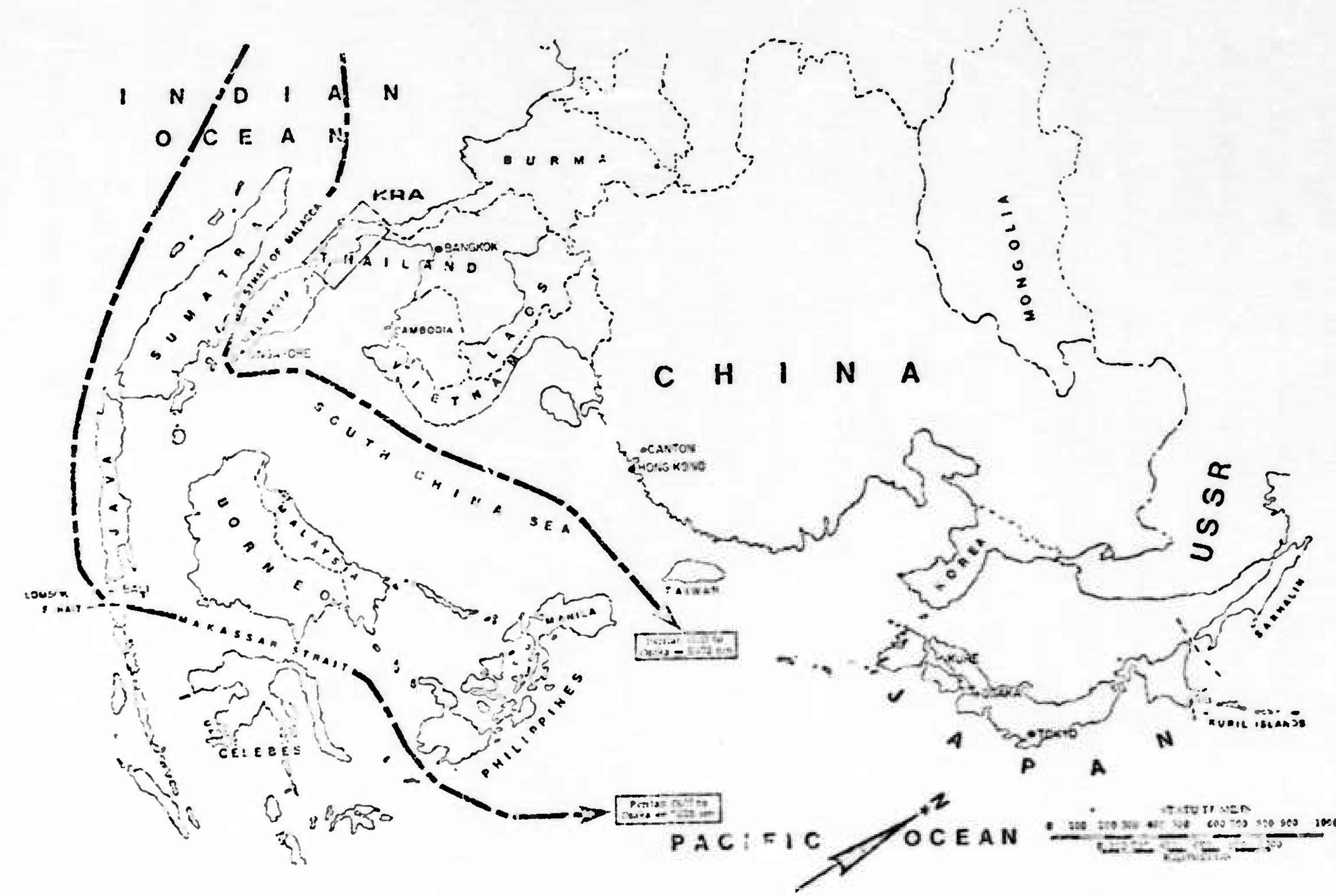


Figure C.19. Tanker Routes in Southeastern Asian Waters having a capacity of greater than 200, 000 dwt or a draft of greater than 25 meters.

Because of the added length and costs of alternate sea routes, Japan has officially claimed that shipping in the Srait should not be restricted. Her claim has received support from the United States, USSR, and Great Britain; the Peoples Republic of China has supported Malaysian and Indonesian claims.[52] At the same time that it is restricting shipping through the Malacca Strait, Indonesia is requesting financial assistance from Japan for domestic oil development. Although Indonesia has potential resources to supply a large percentage of Japan's imports in the future, there are no prospects that Indonesian oil could reduce Japan's dependence on Middle East oil to an extent significant enough to reduce Japan's interest in keeping the Malacca Strait open to larger tankers.

Appendix D

SUMMARY OF JAPANESE SOURCES OF NATURAL GAS

D.1 General

Japan has a limited production of natural gas from domestic gas fields and is turning more and more to imports of liquified natural gas (LNG) to satisfy the demand for clean fuel for electrical generating plants around major cities. Domestic gas as well as LNG imports accounted for about 1 percent of the energy consumed in Japan from petroleum sources in 1971.

Total world energy resources represented by estimated reserves of natural gas (about 470×10^{15} kilocalories) are only about one-fourth of those represented by reserves of oil (about 1823×10^{15} kilocalories).(15) However, over 90 percent of oil reserves are located in countries with low domestic energy demands whereas only about 60 percent of the world gas reserves are in such areas. Natural gas, therefore, constitutes far less a resource than oil, but has a higher portion of its resources in areas that have a high demand for it. This, plus the fact that natural gas is preferred for economic and environmental considerations in the heavily populated industrial nations, means that the world demand for gas is expected to accelerate in comparison to the demand for oil. Because this is especially true for Japanese energy needs, future conflicts over resources and markets for natural gas may be out of proportion to the absolute share of the energy market that it represents.

D.2 Domestic Sources

Japan has a long history of domestic gas production from many small fields, mostly occurring in association with oil fields along the western coast of Honshu and Hokkaido Islands and in a dry gas field in the Chiba fields east of Tokyo on the eastern coast of Honshu (Figure D.1). Production has been through many small wells; gas fields are subject to relatively rapid depletion.

Although domestic production has risen from 600 million to 2.4 billion cubic meters in the past ten years (Table D.1), the rate of exploration has been very low both on land as well as in offshore areas. Proven reserves in 1971 were about 10 billion cubic meters, or only about four years worth of production at the 1971 rate. By one measure of the potential offshore oil and gas resources, the area of continental shelf adjacent to territorial coastlines, Japan ranks tenth among the nations of the world. The rank is shown in Table D.2, which accounts for two-thirds of the world's continental shelf area.[53] Although reserves normally rise slowly as production increases, and Japan is estimated to have ultimate potential resources in the range of 300 to 3000 trillion cubic meters in onshore and offshore areas,[15] production is not expected to rise at a rate that would give domestic natural gas a significantly larger share of Japan's energy market during the rest of this century.

Modest exploration including geologic, geophysical, and exploratory drilling activity for oil and gas is being carried out by Japanese companies, chiefly the Teikoku Oil Company and the government controlled Japan Petroleum Development Corporation (JAPEX). In offshore areas, exploration concessions have been granted to foreign companies, but only as minority partners with Japanese companies. Offshore

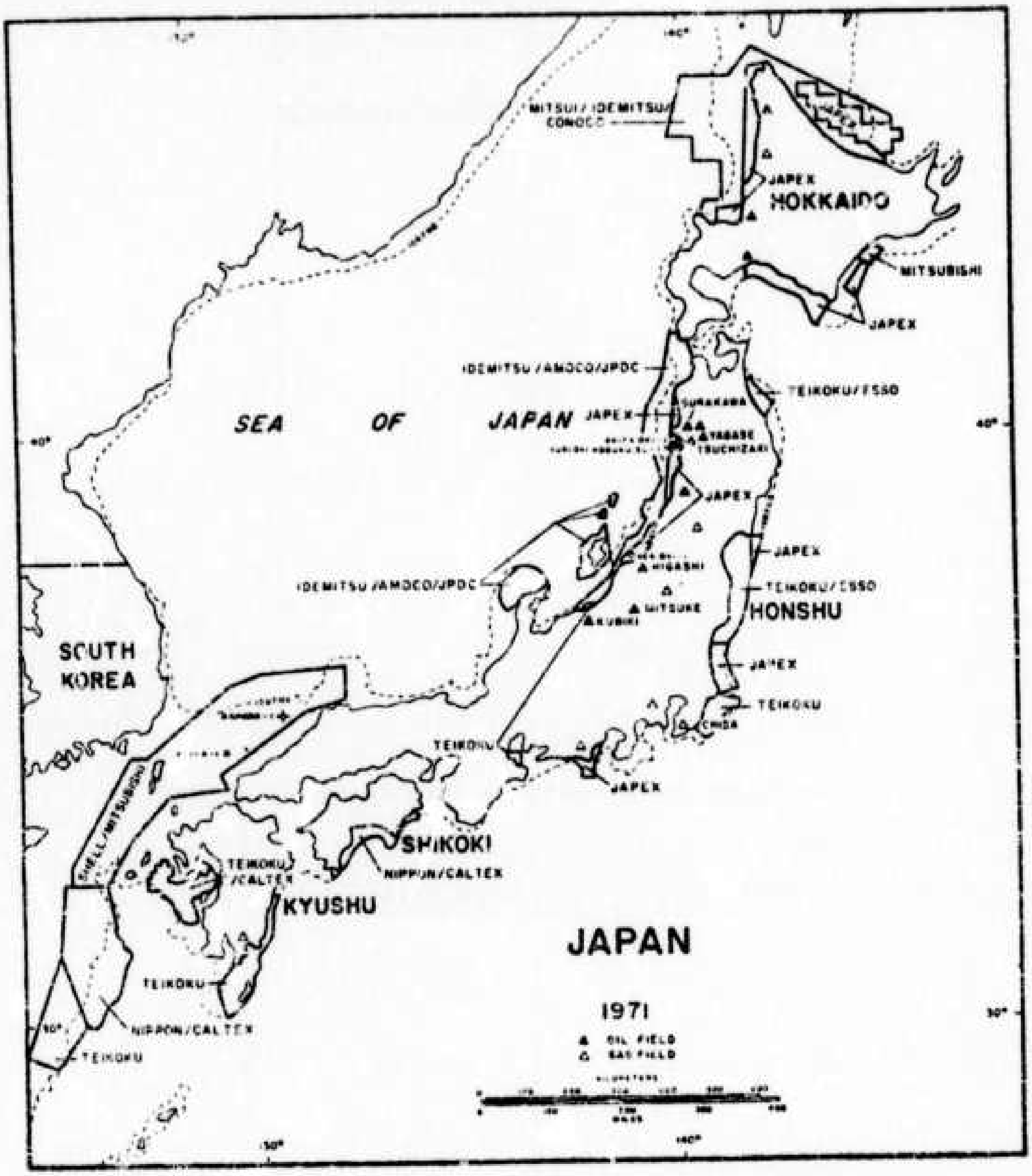


Figure D.1. Japan: Offshore Concessions and Oil and Gas Fields

Table D.1. Japan: Natural Gas Production, 1960-1971

Year	Quantity (10^9 m^3)
1960	0.4
1961	0.6
1962	0.9
1963	1.4
1964	1.3
1965	1.3
1966	1.3
1967	1.3
1968	1.4
1969	1.5
1970	1.7
1971	2.4

Source: Reference 15

Table D.2. Areas of Continental Shelf by Country

Country	Area (Sq. Nautical Miles)
Canada	846,500
Indonesia	809,600
Australia	661,600
United States	545,500
USSR	364,300
Argentina	232,200
China (PRC)	230,100
Brazil	224,100
United Kingdom	143,500
Japan	140,100

Source: Reference 53

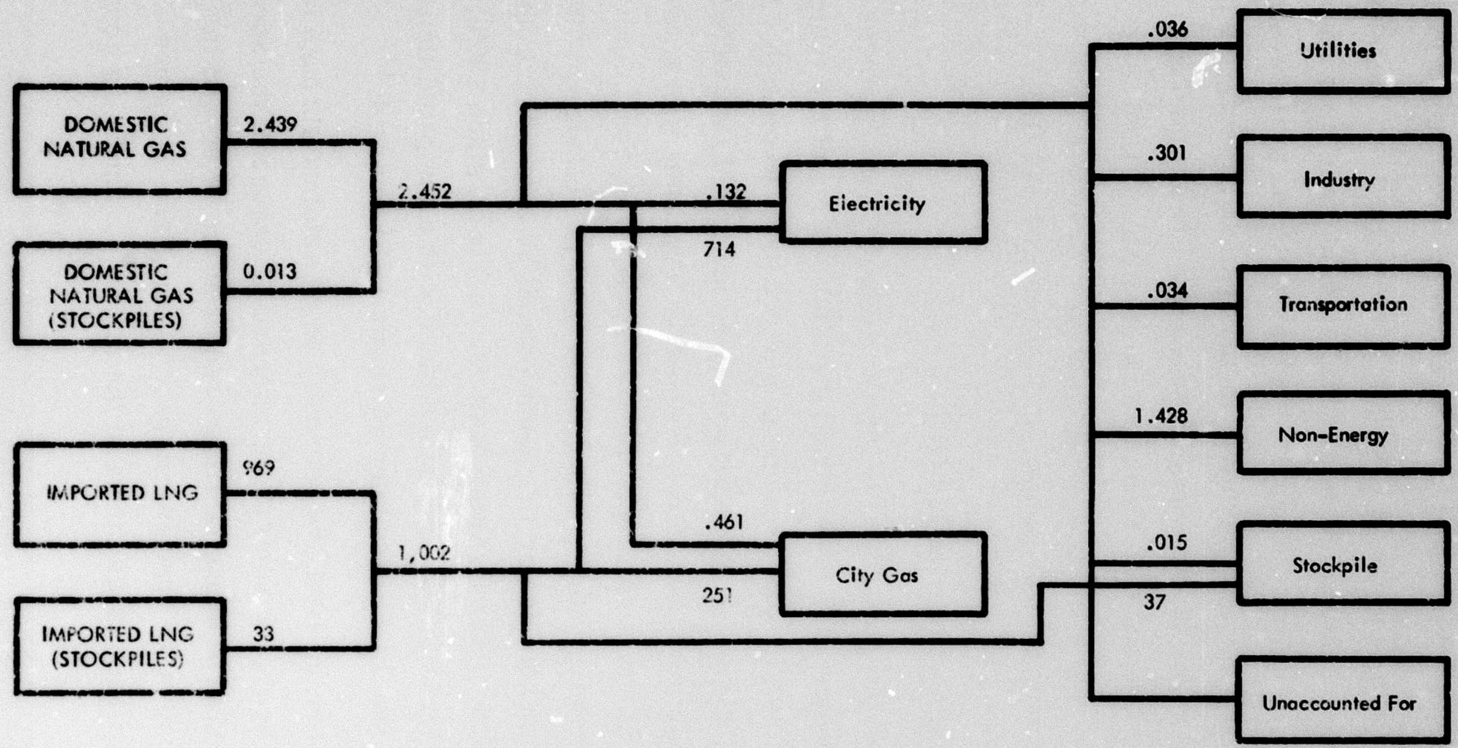
concessions and exploratory wells in 1971, as shown in Figure D. 1, indicate the major areas of activity for gas exploration in Japan.

Most natural gas fields, existing and prospective, lie beneath coastal lowlands or beneath the continental shelf adjacent to such lowlands. Because of this relationship, most domestic natural gas in Japan is consumed largely by petrochemical industries located near the producing gas fields. Lesser amounts are used for city gas in Tokyo and other local cities and for electrical generating plants. LNG is imported exclusively for use in electric generating plants of Tokyo. The patterns of supply and consumption are shown in Figures D. 2 and D. 3.

D. 3 Imported Natural Gas (LNG)

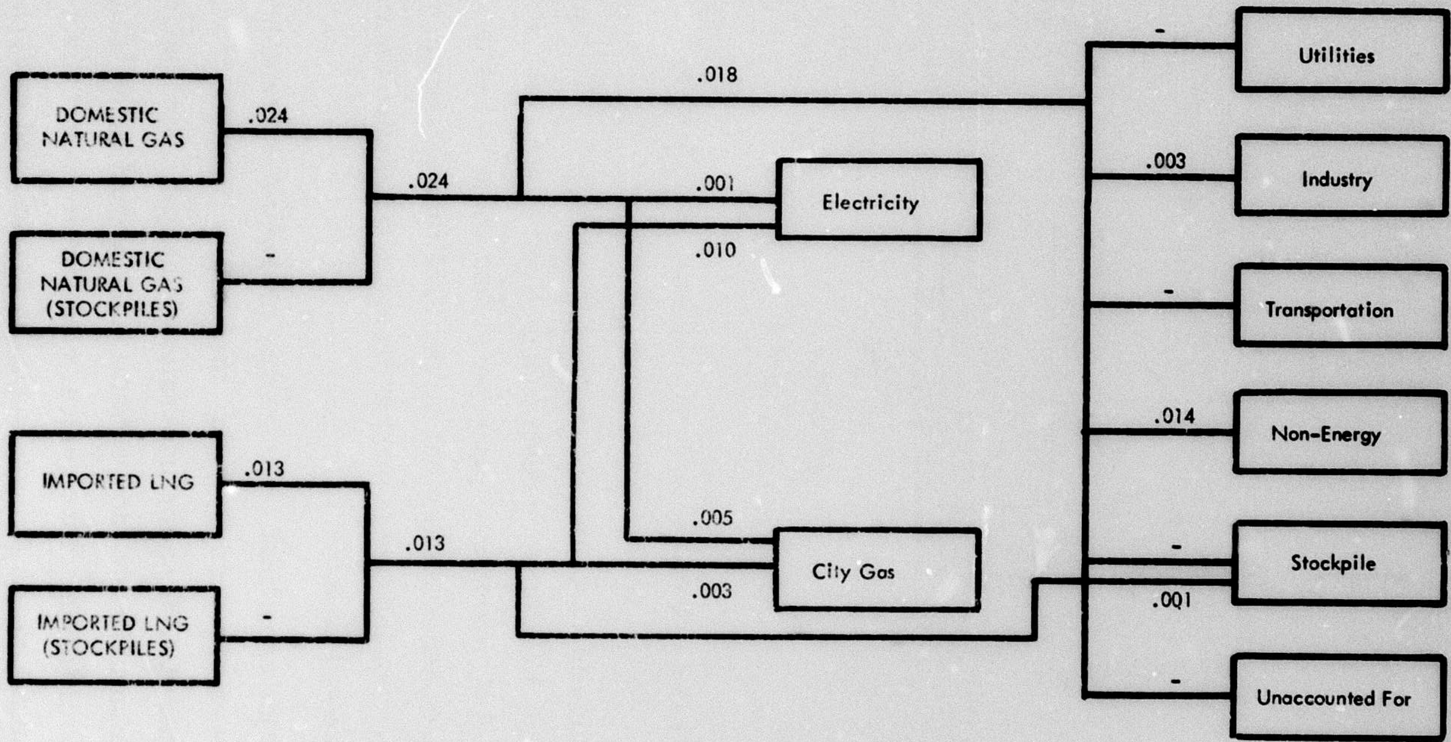
Increased imports of LNG figure prominently in Japanese energy resource planning, even though the total portion of the future energy resource base represented by gas is not likely to be high. Current energy projections by Japan anticipate a rise in LNG imports from about 1 million metric tons in 1971 to about 18. 1 million metric tons in 1980. In the projections developed for this study, LNG consumption would equal 3 percent of the energy derived from petroleum, in 1980. Growth in LNG imports during this period would be based on a continuation of imports from Alaska (which have been going on since 1969), and Brunei (which started in late 1972), combined with anticipated imports from Abu Dhabi and the Soviet Union as shown in Figure D. 4. [5]

All imports of LNG are currently being obtained through firms in which Japan has full or controlling interest. Because of the specialized transportation and processing facilities required for LNG, and the aggressive bidding by Japan for foreign natural gas supplies, the future should see extensive Japanese investments in the major gas exporting countries



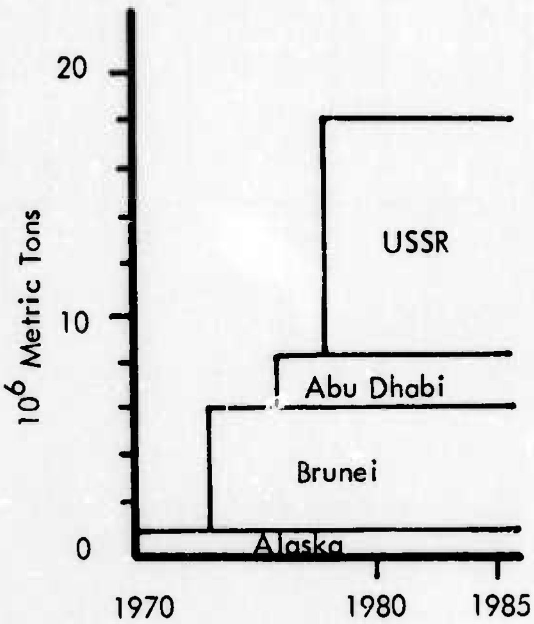
Units: Gas in 10^9 m^3; LNG in 10^3 MT
Source: Reference 2

Figure D.2. Japanese Supply and Consumption of Natural Gas, 1971



Units: 10^{15} kilocalories
Source: Reference 2

Figure D.3. Japanese Supply and Consumption of Energy from Natural Gas, 1971



Source: Reference 3

Figure D.4. Projected Japanese LNG Imports, 1970-1985

in pipelines, liquification plants, and port facilities, in addition to the already massive LNG tanker construction effort. Such complete network of control of production, processing, and shipping and the fact that much of the processing is done before the LNG reaches Japan, permits a much tighter coordination of production and consumption than is the case with crude-oil imports.

A major constraint on importing LNG is the extremely high transportation and processing costs; these costs limit the economic competitiveness of LNG on the international market. For Japan, this has meant temporarily abandoning some LNG-import plans from the Middle East while giving more serious attention to such circum-Pacific sources of natural gas as Brunei, southern Alaska, and eastern Siberia.

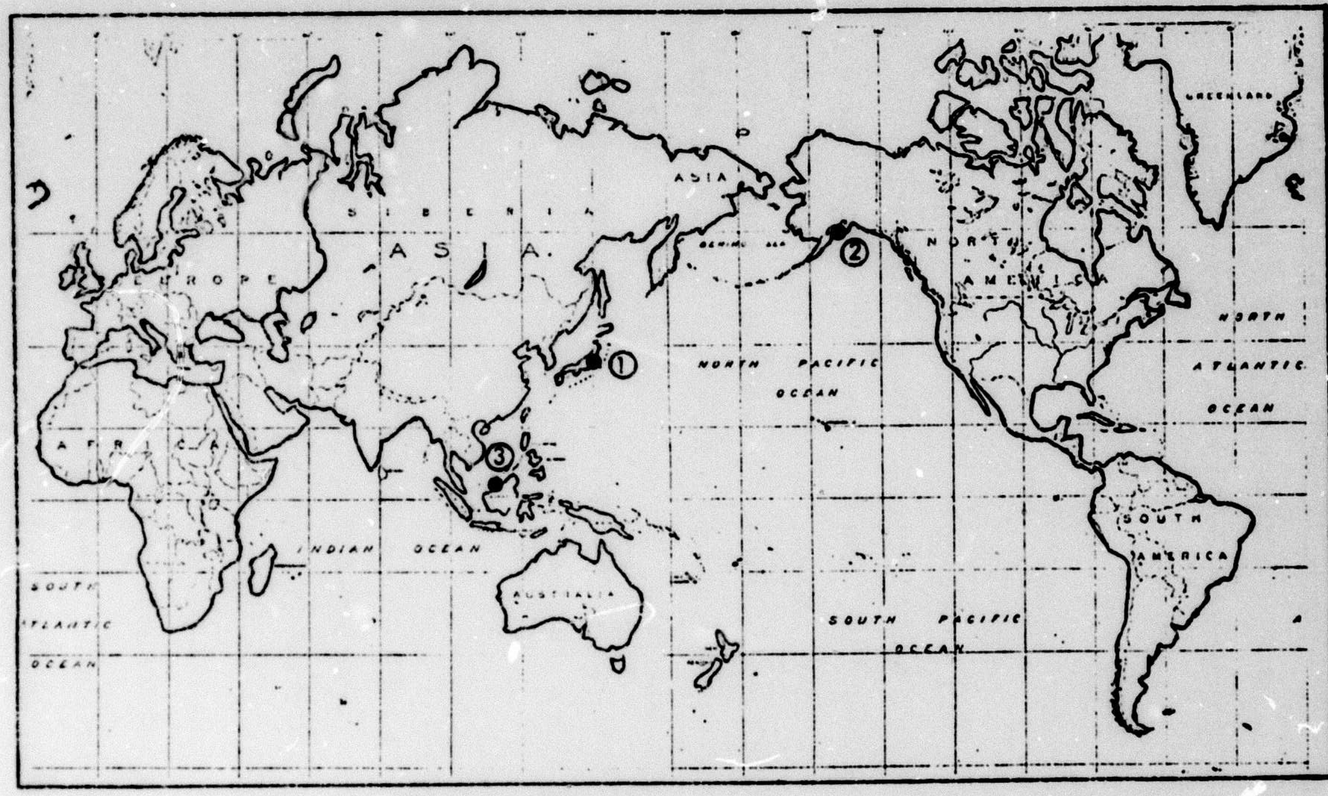
There is no doubt, however, that because LNG is an environmentally preferred fuel it will make up an increasingly larger portion of Japan's energy resource base in the 1980-2000 period. LNG is currently consumed exclusively in city utilities; existing contracts for LNG from Alaska and Brunei are with the Japanese utility companies Tokyo Electric, Tokyo Gas, and Osaka Gas.

Japan is now pursuing intensive negotiations throughout the world for additional LNG supplies. Most areas of interest are in offshore gas fields which will require large investments in pipelines and processing facilities. Japanese companies are actively involved in seeking additional LNG supplies from most areas of the world where natural gas discoveries have indicated large reserves, and where countries do not have large energy demands. In addition to Alaska and Brunei, Japanese interests in natural gas have been indicated in Abu Dhabi, Africa, Alaska, Australia, Brunei, Indonesia, Iran, Neutral Zone, and USSR. These areas are located on the accompanying maps (Figures D.5 and D.6) and are briefly described below.

D.3.1 Abu Dhabi

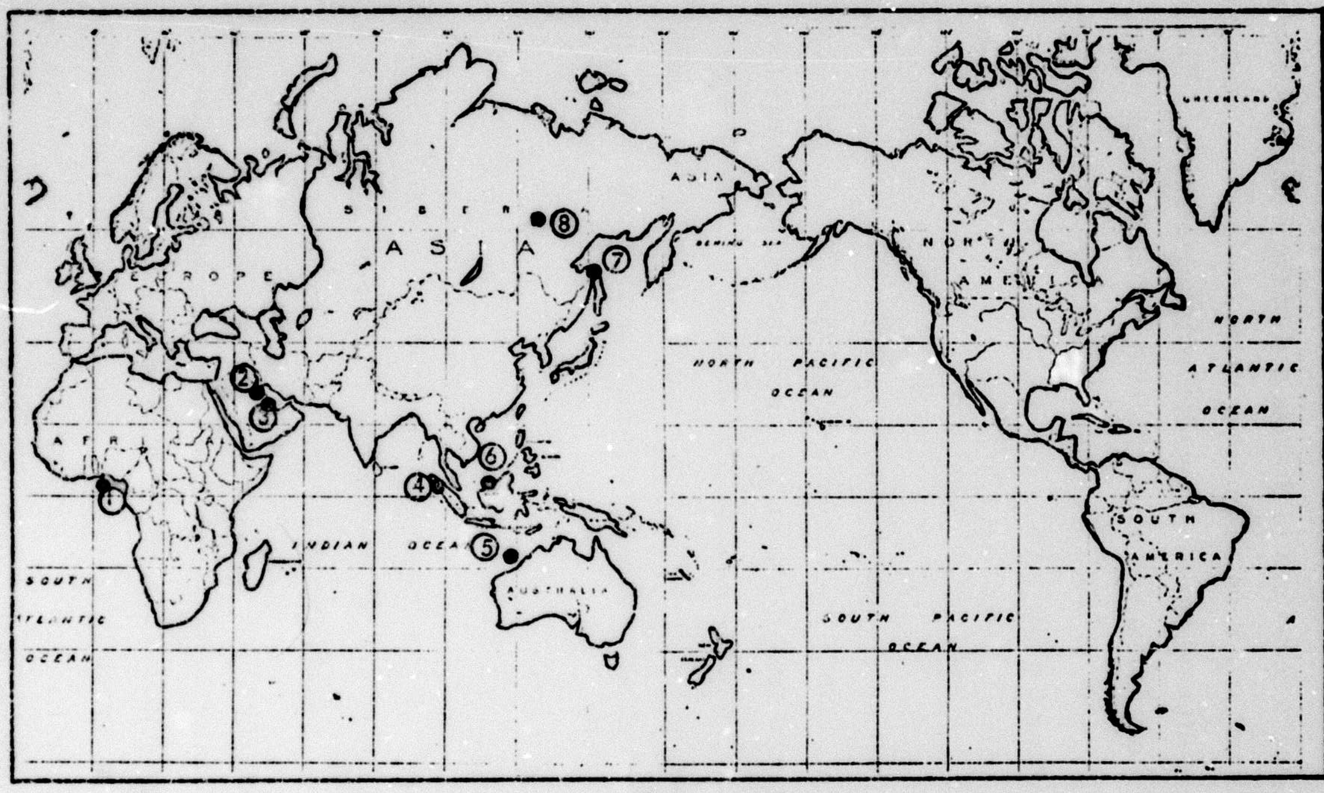
Japan plans to begin LNG imports from Abu Dhabi in 1976. Abu Dhabi, the largest of the seven semi-independent Trucial shiekdoms along the southern coast of the Persian Gulf, has offshore reserves of natural gas estimated at 283 x 10^9 cubic meters (202 x 10^6 metric tons LNG)[15] but currently has no production. Studies are underway to construct processing and shipping facilities on Das Island.

Agreements have been recently announced that will provide for shipments beginning in 1976 of 3 million tons of LNG per year from the Umm Shaif gas field under a 20-year contract with Tokyo Electric Power Company.[54]



1 Domestic Fields
2 Cook Inlet, Alaska
3 Brunei

Figure D.5. Existing Sources of Natural Gas for Japan



1	Nigeria	5	Australia
2	Iran	6	Brunei
3	Abu Dhabi	7	Sakhalin Island
4	Sumatra	8	East Siberia

Figure D.6. Future Sources of Natural Gas for Japan

D. 3. 2 Africa

The Japanese-owned Japan Petroleum Company (Nigeria), Ltd., has major offshore concessions in Nigeria and in the Congo. Although no production or imports have begun from these concessions, good discoveries of low-sulfur oil have been made; proven reserves of natural gas in these offshore areas are 280 billion cubic meters (which equals 200 million metric tons of LNG)[15] with potential resources estimated as high as 3000 billion cubic meters.

D. 3. 3 Alaska

Japan currently imports about a million metric tons of LNG from the Cook Inlet gas fields in southern Alaska. This represents the bulk of the production of natural gas from these fields, with the exception of small amounts used locally. Estimates of natural gas reserves in Cook Inlet are 120 trillion cubic feet (3. 36 trillion cubic meters).[15] Additional processing facilities would be needed to increase LNG production.

D. 3. 4 Australia

Australia has gas reserves estimated at 700×10^9 cubic meters, including both onshore and offshore areas. Continued discoveries indicate that Australia could become a major world exporter of LNG.

Although Japan has no exploration, production, or refining interests in Australia, discussions are underway concerning the possibility of Japanese imports of LNG from an international group of oil companies that is currently developing high potential gas fields off the northwestern Australian coast. Estimates of these fields, for which Japan could become the major customer, has put reserves at 140×10^9

cubic meters. Japan would probably become the chief developer of the necessary LNG facilities, costs of which have been projected from 500 million to a billion dollars.(13)

D. 3. 5 Brunei

Brunei is now the chief supplier of LNG to Japan. In 1970, a 20-year contract was negotiated by Japanese utility companies to provide 1.5 million metric tons of LNG per year and in 1972 another contract for 3.7 million metric tons was signed; maximum shipments will be reached in 1975. The gas is being sold by Brunei Shell Petroleum Ltd.; the LNG liquification facility in Brunei is jointly owned by the Brunei government and several foreign oil companies including Mitsubishi of Japan. Gas reserves are estimated at 212×10^9 cubic meters.(13)

D. 3. 6 Indonesia

Negotiations between the Japanese-controlled company with both a private as well as the Indonesian state-owned company are currently underway aimed at supplying about 1 million metric tons of LNG per year from the gas fields of the Arun area of North Sumatra, beginning in 1978.(55) This would require extensive Japanese investments in pipelines, liquification plants, tankers, and port facilities in Sumatra.

D. 3. 7 Iran

For the past few years, the Japanese government has expressed interest in a joint venture to obtain LNG from Iranian gas fields in the Persian Gulf. Iran has offshore reserves of about 5700 billion cubic meters of natural gas (4.07 billion metric tons of LNG) and potential resources of as much as 30,000 billion cubic meters (20 billion metric tons of LNG).[15] With an annual production in 1971 of about 37 billion cubic meters (26 million metric tons of LNG),[13] Iran represents a potential major source of LNG for Japan.

In late 1972, however, it appeared that prohibitive costs involved in processing and transporting LNG under existing market conditions would lead to the abandonment of the project.[5] Later reports indicated that negotiations were still underway aimed at supplying 5 million metric tons of LNG per year beginning in 1977.[56] In any case, it appears reasonable that Iran will eventually become a major supplier of LNG to Japan.

D.3.8 Neutral Zone

The Japanese Arabian Oil Company is currently undertaking vigorous offshore exploration in the Dorra gas field in the Persian Gulf off the Neutral Zone. This field is believed to be one of the largest in the Middle East with a potential production of 10 million metric tons of LNG per year.[29]

D.3.9 USSR

Large deposits of natural gas have recently been discovered in the Vilyuy Basin north of Yakutsk in eastern Siberia (Figure D.7). Proven reserves are about a trillion (10^{12}) cubic meters (700 million metric tons LNG) and potential resources have been estimated at 13 trillion cubic meters (9 billion metric tons LNG).

The East Siberian gas fields are remote from domestic markets and so there is a need for foreign markets outlets. Since the first discoveries in the Vilyuy Basin, Japan has made known its interest in a natural gas pipeline from the Yakutsk area to the coast. Late last

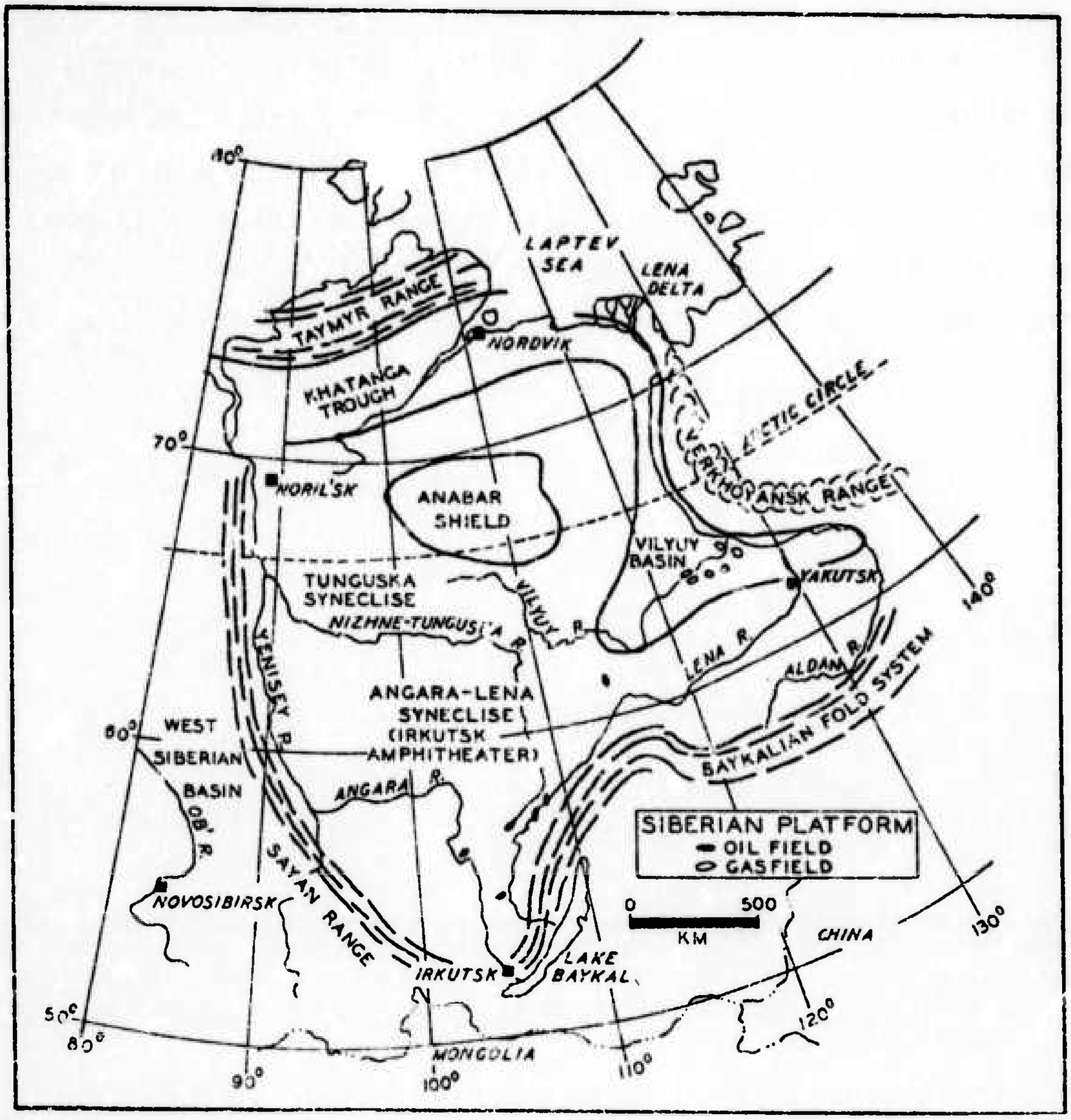


Figure D.7. Oil and Gas Fields of East Siberia

year, USSR and Japan came to an understanding that Japan will purchase 15 billion cubic meters of gas per year (10 million metric tons LNG) beginning in 1978 and that joint development will also include the United States in addition to Japan and USSR.(57) Recent agreements between U.S. companies and the Soviet Union, however, made no mention of Japanese participation in a joint venutre with the U.S.

In addition to the Vilyuy Basin, large potential resources of natural gas exist in the continental shelf off North Sakhalin Island and are currently subject of intensive exploration activities. As the nearest market for such gas, Japan has for several years shown interest in a pipeline to bring natural gas from North Sakhalin to Japan.[13] No firm proposals or plans are known, however, to construct such a pipeline.

Appendix E

NUCLEAR ENERGY GENERATION

E.1 Background Information

The primary nuclear energy material for present reactors is uranium ore. Only the uranium -235 isotope of the uranium ore will fission and release energy, and the uranium -235 isotope occurs naturally as only 0.7 percent of the total uranium. For use in present day light water reactors, LWR's, the U-235 isotope must be concentrated about 4 times to around 3 percent in fuel enrichment facilities. The remainder of natural uranium is uranium -238 which, while it does not directly fission to an appreciable extent, is converted to fissile plutonium isotopes through transmutation. In present day LWR's with partial recycle of the plutonium produced, about one-half of the total energy released in a reactor will come from the U-235 and one-half from plutonium which was created from the U-238 content of the uranium.

As noted above, present LWR's, such as those Japan is presently using, obtain an appreciable amount of their energy directly from the rare U-235 isotope and only a small amount of the much more abundant U-238 isotope is ultimately used to produce energy. That is, present LWR's are inefficient in converting U-238 to a fissile form (plutonium). Japan is actively pursuing a program to develop advanced convertor reactors which would convert a greater fraction of the U-238 to plutonium for fissioning. Such reactors would reduce the requirement for uranium ore by several fold. Japan is also actively pursuing the development of a breeder reactor, i.e. a reactor which converts the non-fissile U-238 to fissile fuel faster than the original fissile fuel is used up. Breeder reactors do not create something for nothing, but do make the total uranium content, U-235 plus U-238, available as fuel. Development of convertor and breeder reactors will greatly reduce the amount of uranium ore required and at the same time make power production much less sensitive to fuel costs. These are decided advantages to a nation such as Japan with limited, low-grade uranium resources.

One of the obvious advantages of nuclear fuel lies in the relatively large amount of energy obtainable from a small amount of fuel. As a consequence the frequency and amount of fuel needed in refueling is greatly reduced. To quantify this difference, note that a typical 1000 MW electric LWR generating plant will require about 170 metric tons of natural uranium for a year of continuous operation, while a 1000 MW fossil-electric plant would require about 1.2×10^7 bbl/year. To supply the conventional fossil plant would require five 350,000 ton shiploads of oil, while the nuclear fuel could be shipped in a single small freighter, or even air freighted. In terms of the enriched uranium fuel which Japan would actually ship (Japan at present has no enrichment facilities and is entirely dependent upon the U.S. for enriched fuel), the nuclear fuel requirement would be further reduced to about 40 metric tons/year. Further, because of its high energy density, a substantial amount of energy in the form of uranium fuel can be readily-stockpiled. Thus, a viable nuclear industry offers Japan an energy source whose fuel supply is less vulnerable in crisis situations than are conventional fuels such as oil.

A further advantage of nuclear power generation is that power costs are not strongly affected by uranium costs. That is, for a typical 100 MW electric LWR total nuclear fuel cycle costs amount to only about 20 percent of the total cost of generating and transmitting electricity (only about 2 mils/KWH out of a total ge generating cost of 10 mils/KWH). Of the total fuel cycle costs only about 1/3 are due to the cost of the uranium ore itself. Thus, if uranium ore prices were to double from the present level of $8 per pound U_3O_8 to $16 per pound U_3O_8, power costs would be affected by less than ten percent. This is quite important to a country such as Japan which must depend upon others for the uranium ore supply in that it means, within reasonable ranges, increases in nuclear fuel costs will not retard the growth of nuclear power. In the future when breeder reactors are introduced the requirements for uranium ore will be reduced to the point that uranium costs will be insigificant even at levels of 10 tens times present fuel costs. This means while Japan's presently known uranium reserves are not of sufficient quality to be economical for use in LWR's, they will be usable in a breeder reactor economy.

The fact that fuel costs are only a small fraction of the total nuclear power generation cost is a corollary of the fact that nuclear plants are capital intensive. A nuclear reactor requires large amounts of capital and a long lead time to complete. Further, unlike conventional thermal systems in which essentially only a generation plant need be built, nuclear power requires the construction of a whole series of fuel cycle facilities as shown in Figure E.1. Japan is presently developing capabilities in fuel fabrication and fuel reprocessing, and presently has the capability to build U.S. designed

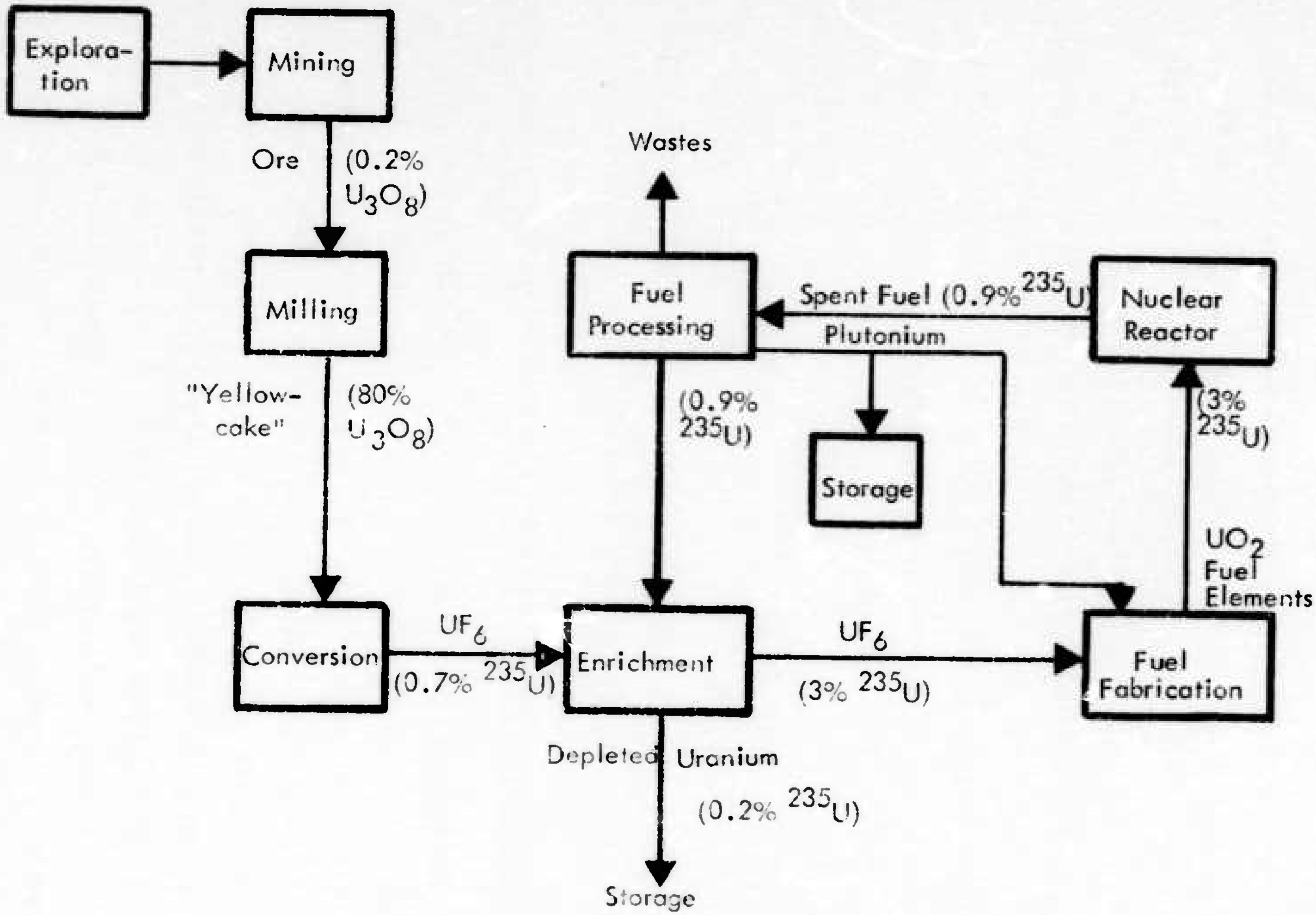


Figure E.1. Typical Light Water Reactor Fuel Cycle nuclear reactors. However, primarily due to treaty restrictions, the development of enrichment facilities which could be used for making weapons material has not yet begun in Japan. Presently Japan is entirely dependent upon the United States for enriched uranium fuel.

The large amounts of capital needed and long lead times associated with nuclear power are a definite disadvantage in terms of being able to quickly increase capacity. Thus, while nuclear power is not as sensitive to changing fuel costs, it is also not flexible enough to meet short-term crisis demands for more power.

Nuclear reactors also have certain environmental advantages and disadvantages in relation to conventional thermal power plants. The chief advantage being that nuclear plants do not emit combustion products. Japan is increasingly becoming more environmentally aware and pressures to reduce air-borne emissions of combustion products will begin to strongly influence power generation policies. In particular, steps to reduce sulfur emissions coupled with an increasing difficulty in obtaining low-sulfur coal and oil will give strong impetus to Japan's nuclear industry. Nuclear reactors, however, do create and release small amounts of radioactivity to the environment. These releases though they may create no obvious environmental effects are apt to create strong public fears. The consequences of serious accidents associated with nuclear reactors are also very apt to be very much more severe than any conceivable accidents at fossil plants. Thus, while nuclear accident probabilities may be very low, nuclear reactors often raise serious safety concerns which are apt to be reflected in delays of building and operating nuclear plants.

Nuclear reactors are also at a disadvantage in relation to conventional fossil plants in terms of thermal discharges. Present nuclear reactors have thermal efficiencies on the order of 32 percent while modern fossil plants have efficiencies on the order of 40 percent. In addition, in a fossil plant, an appreciable amount (approximately 25%) of the waste heat is released up the stack with the exhaust gases while in a nuclear plant essentially all of the waste heat is rejected to the cooling water. The net result is that nuclear plants reject 50 to 60 percent more waste heat into the cooling water than do similar electrical-output fossil plants. What with the growing concern in Japan over thermal discharges into fishery areas, the high waste heat dump of nuclear plants may place additional constraints on future nuclear plants in Japan. Advanced reactor concepts, particularly sodium cooled breeder reactors and high temperature gas cooled reactors, have higher thermal efficiencies than present LWR's and could reduce the thermal effluent problem.

Nuclear reactors have a final disadvantage in relation to conventional energy sources in that they are economical only in very large scale and are not easily adapted to many transportation and industrial energy requirements. For this reason, it is doubtful if nuclear energy will account for more than 25 percent of Japan's total energy requirement anytime in this century, unless advanced technology in many other fields is developed. For instance, the development of efficient electrical storage or conversion systems (such as electrolysis of water to produce hydrogen) could allow the central generation of nuclear power which could then be used in individual units such as cars. Japan is presently pursuing an attempt to make practical the use of heat from nuclear reactors in industrial processes such as steel making. However, to be practical this will require the development in Japan of advanced high-temperature gas reactors.

E.1.1 Historical Summary

As a result of World War II treaty restrictions and as a result of the general aversion in Japan to nuclear development following the war, Japan did not have any nuclear program in the 1940's or early 1950's. In fact, Japan's first nuclear reactor was not completed until 1957 and was a simple pool-type research reactor. It was not until 1965 that Japan had her first commercial reactor, which was of British design and had an electrical capacity of 166 MW. Starting in the late 1960's, however, Japan began an active program to develop nulcear energy for large scale commercial use. At present, all reactors built or being built for commercial use, except for the first 166 MW British reactor, are light water reactors (LWR's) of U.S. design. These reactors have been built by Hitachi and Toshiba under licensing agreements with General Electric, and Mitsubishi under licensing agreements with Westinghouse. Through the remainder of the 1970's light water reactors of U.S. design will probably remain the mainstay of the Japanese nuclear power industry. The commercial reactors built or being built in Japan[58] are listed in Table E.1.

The installed nuclear capacity for generating electricity is shown in Figure E.2. As can be seen, the nuclear power industry has gone from zero electrical capacity in 1965 to 1823 MWe at the end of 1972.[59] As can be seen in Figure E.2, however, nuclear power still only accounts for a very small fraction of the total electrical power production within Japan. Thus, historically nuclear power cannot be said to have played an important part in meeting the energy needs of Japan, and through the remainder of the 1970s nuclear energy is not apt to be a major energy source within Japan. However, Japan is a resource-poor country with tremendous energy requirements so nuclear

Table E.1. Power Reactors in Japan[58]

Names of Reactors	Location	Type	Thermal Output (KW)	Criticality Date
Tokai Power Reactor	Tokai-mura, Ibaraki Pref.	Advanced Calder Hall	595,000 (166,000 e)	May 4, 1965
Tsuruga Power Reactor	Tsuruga City, Fukui Pref.	BWR	970,000	(Dec. 1969)
Toden Fukushima Power Reactor 1	Ohkuma, Futaba-cho, Fukushima Pref.	BWR	1,200,000 (400,000 e)	(Oct. 1970)
Kanden Mihama Power Reactor 1	Mihama-cho, Fukui Pref.	PWR	1,031,000 (325,000 e)	(July 1970)
Toden Fukushima Power Reactor 2	Ohkuma, Futaba-cho, Fukushima Pref.	BWR	2,380,000 (784,000 e)	(May 1973)
Kanden Mihama Power Reactor 2	Mihama-cho, Fukui Pref.	PWR	1,460,000 (500,000 e)	(July 1972)
Chugoku Shimane Power Reactor 1	Kashima-cho, Shimane Pref.	BWR	1,380,000 (460,000 e)	(Nov. 1973)
Kanden Takahama Power Reactor 1	Takahama-cho, Fukui Pref.	PWR	2,440,000 (826,000 e)	(Oct. 1973)
Toden Fukushima Power Reactor 3	Ohkuma, Futaba-cho, Fukushima Pref.	BWR	2,380,000	(May 1974)

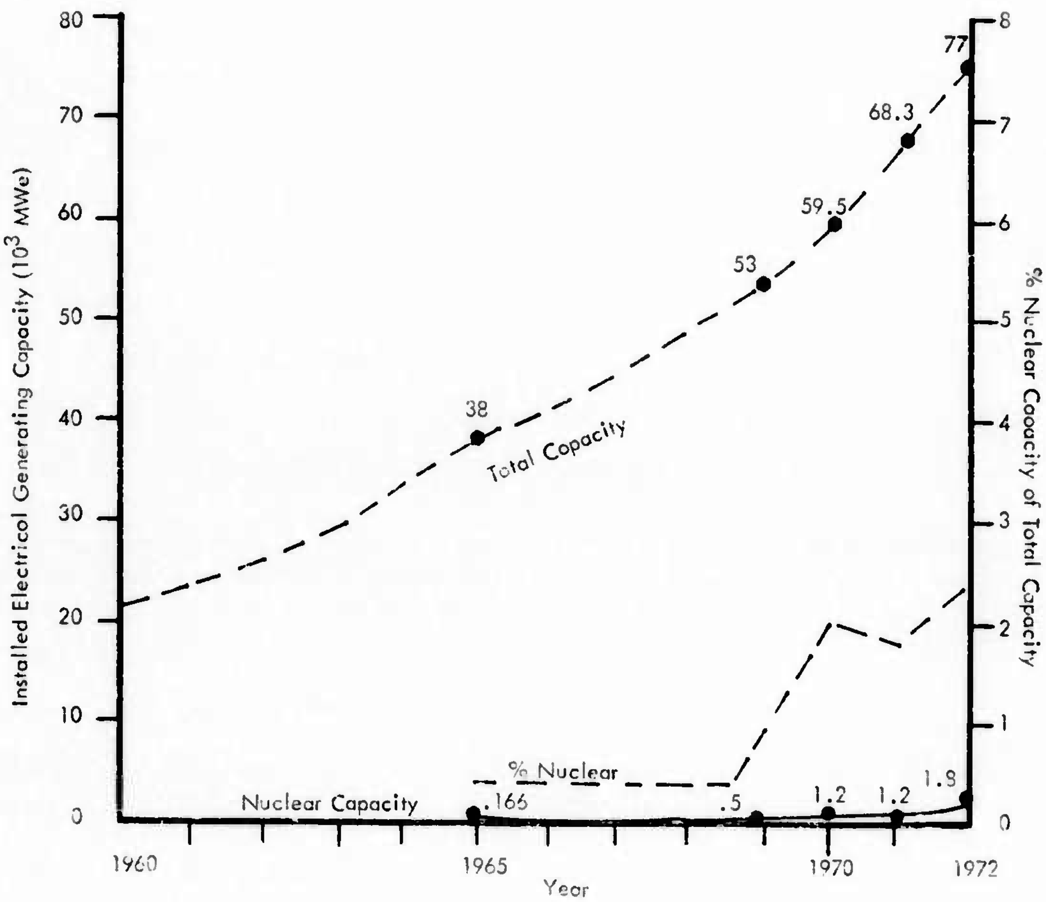


Figure E.2. Installed Electrical Capacity in Japan power is very important to Japan and is being pursued very vigorously. By the turn of the century nuclear energy is expected to be the main source of electrical power in Japan, and is expected to be a significant part of Japan's total energy production.

E.1.2 Projected Nuclear Power Growth

The SAI base case energy projections for nuclear power through year 2000 are shown in Figures E.3 and E.4. As can be seen in Figure E.3, installed nuclear-electrical generating capacity is expected to show a rapid increase, with nuclear power going from about two percent of total electrical generating capacity in 1971 to about 42 percent of total electrical capacity in 2000. In terms of energy production* rather than energy capacity, Figure E.4, nuclear energy will be even more significant since nuclear energy will eventually take over nearly the full base load production of electricity with other means of electrical production used primarily to meet peak demands. Thus, in terms of energy production by year 2000 nuclear energy will account for 64 percent of total electrical production and 25 percent of the total energy supply in Japan.

Through 1978, the Japanese Electrical Power Industry plans for installation of new power are fairly fixed and amount to an increase in total electrical capacity of about 9 percent per year. Beyond 1978 the growth in electrical power in Japan will slow somewhat, but electrical power growth will continue to be faster than overall power growth through year 2000 due to the rapidly increasing demands of the consumer segment of Japan.

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* Note energy production values in Figure E.4 are electrical outputs at sending end of electrical utilities, captive industrial electrical power is not included.

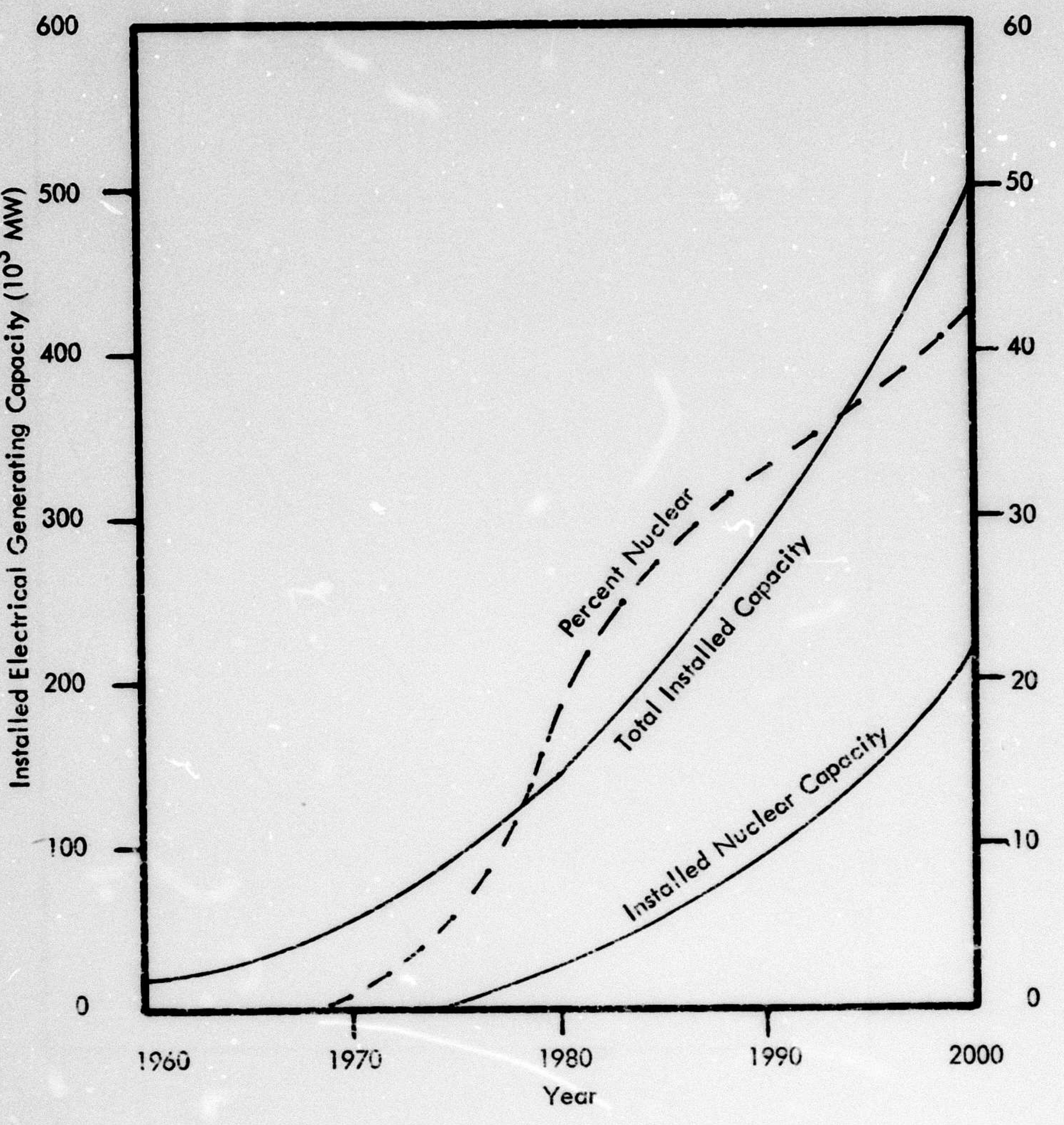

Figure E.3. Installed Nuclear and Total Electrical Ccapacity

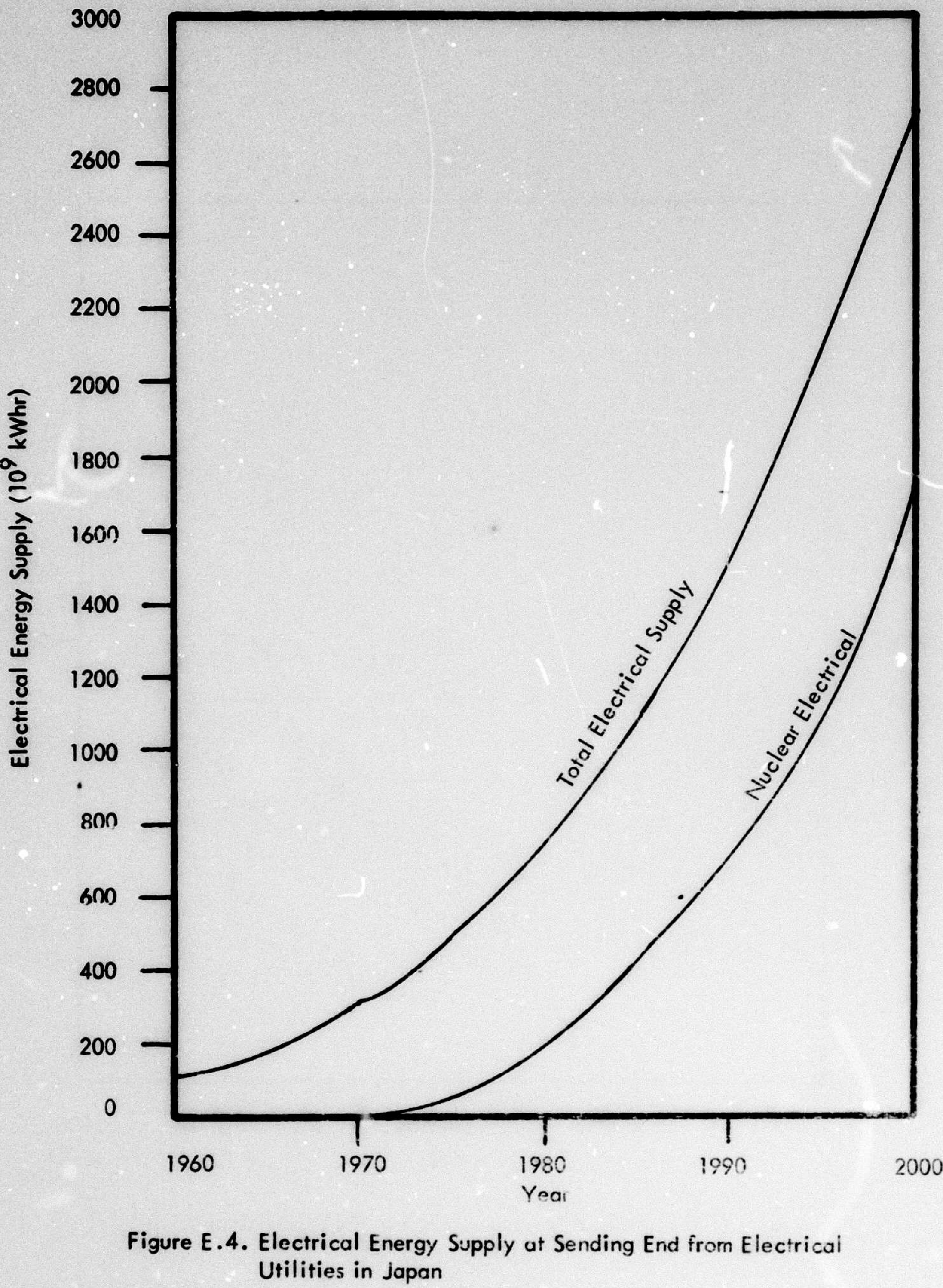

Figure E.4. Electrical Energy Supply at Sending End from Electrical Utilities in Japan

E.2 Nuclear Resources Requirements

E.2.1 Light Water Reactor Requirements

At present, essentially all of Japan's nuclear generating capacity comes from light water-moderated and -cooled reactor plants (LWRs). Through the remainder of this decade, LWRs will most likely remain the mainstay of the Japanese nuclear industry. The split by reactor type beyond 1980 is uncertain, but the maximum resource requirements can be scoped by assuming a pure LWR economy through the year 2000. To place an upper bound on uranium requirements, it will be further assumed that there is no plutonium recycle to the LWRs. The uranium ore requirements with the above assumptions are summarized in Table E.2. To put these values in perspective, note that Japan's uranium resources as discovered by 1969 represented only 7,700 metric tons of uranium. As a further means of putting Japan's uranium resources in perspective, note that 7,700 metric tons of uranium used in LWRs represents only 45,000 MW years of electrical power which is equivalent to about one year's electric power consumption in Japan at present rates.

Table E.2. Projected Japanese Uranium Requirements assuming Pure LWR Industry with no Plutonium Recycle

Year	Cumulative Uranium Requirements (Metric Tons U_3O_8)	Cumulative Enrichment Requirements (10^3 Kg SWU)*
1975	8,000	4,000
1980	36,000	17,000
1985	90,000	43,000
1990	180,000	88,000
2000	510,000	252,000

*Kg SWU = kilograms of Separative Work Units

The uranium discovered to date in Japan is of low quality which is not economically competitive, and Japan is supplying essentially none of its own uranium at present. There are no indications that the Japanese expect to find significant amounts of high quality ore in Japan, and no large-scale domestic uranium exploration efforts are presently underway. In the present LWR-dominated nuclear industry, Japan can be considered to have essentially no domestic uranium resources.

Unlike conventional fossil-fueled generation systems, nuclear units require complex fuel-cycle systems to support the basic nuclear-electric generating stations. In particular, LWRs require enrichment facilities to convert natural uranium ore to enriched uranium fuel. Japan at present has no fuel enrichment facilities and is entirely dependent upon the United States for enrichment capability. The enrichment requirements needed by Japan under the same assumptions used for the ore requirements, i.e., all LWRs with no plutonium recycle, are given in Table E.2. Japan has just completed arrangements for purchasing 10×10^6 Kg SWU units from the United States for a cost of \$320 million. This should be sufficient to meet Japan's needs until the later part of the 1970s. To place these numbers in perspective, note that at current operating levels, the output of the entire gaseous diffusion plant complex in the United States is about 10×10^6 Kg SWU/year (the ultimate capacity of the current U.S. units is about 17×10^6 Kg SWU/year).

E.2.2 Advanced Reactor Requirements

The incentive for Japan to develop advanced reactor types which can greatly reduce uranium ore requirements and enrichment requirements is very strong, and Japan is vigorously pursuing a national reactor development program to develop an Advanced Thermal Reactor (ATR) and a Fast Breeder Reactor (FBR).

The ATR design chosen by Japan is that of a light water steam cooled, heavy water moderated reactor. The reactor is being designed to operate on a plutonium recycle requiring only natural uranium and recycled plutonium for equilibrium operation. Such a reactor would require no enrichment capabilities for equilbrium operation. The ATR design would also be more efficient in converting the non-fissile uranium-238 isotope to fissile plutonium, and this combined with complete plutonium recycle would significantly reduce the uranium ore requirements. The present plans call for the completion of a prototype ATR in 1974 and actual industrial use of ATRs beginning in 1980. The FBR design chosen by the Japanese is similar to that being developed in several countries, that is a sodium-cooled fast breeder reactor. Development of a complete fast breeder reactor industry would mean that no enrichment facilities would be required and that the requirements for uranium ore would be reduced by the order of 100 from that required by present LWRs without plutonium recycle. Present plants call for the construction of a FBR prototype by 1978 and the industrial use of FBRs by 1990.

The successful development of the advanced reactor types discussed above could alter the uranium ore and enrichment requirements given in Table E. 2. To scope the probable effect of advanced reactors, the requirements given in Table E. 3 have been calculated assuming a very optimistic development of these advanced reactor types. That is, after 1980 it is assumed that commercial ATRs are introduced and that by 1985 all new reactors which begin to operate are ATRs. After 1990 FBRs are assumed to be commercially feasible and by 1995 all new reactors which begin to operate are assumed to be FBRs. Since present LWRs have assumed lifetimes of 40 years, all LWRs presently built or which will be built are assumed to continue to operate through the year 2000. The resource requirement envelope for nuclear power

Table E.3. Projected Japanese Uranium Requirements assuming Operation of ATRs by 1980 and FBRs by 1990

Year	Cumulative Uranium Requirements (Metric Tons U_3O_8)	Cumulative Enrichment Requirements (10^3 Kg SWU)*
1975	8,000	4,000
1980	36,000	17,000
1985	88,000	40,000
1990	160,000	67,000
2000	300,000	120,000

*Kg SWU = kilograms of Separative Work Units

generation, based on the data of Tables E.1 and E.2, is shown in Figure E.5, assuming the base case projection of nuclear power generation given in Figures E.3 and E.4 is met.

As shown in Figure E.5, Japan's requirements for uranium and enrichment work will not be appreciably altered before 1985 by the development of advanced reactor types. By year 2000, Japan's resource requirements will greatly depend on technological progress made in the development of advanced reactor types. However, even with the most optimistic technological developments, the resource requirements by year 2000 will be far in excess of known Japanese domestic resources or already contracted for resources from other countries.

E.2.3 Uranium Ore Sources

In order to procure uranium ore, Japan made contracts for mining and exploration activities with Canada in 1959, with the U.S. and U.K. in 1968, and with France and Australia in 1972. The contracts with the French are in cooperation with the Niger Government

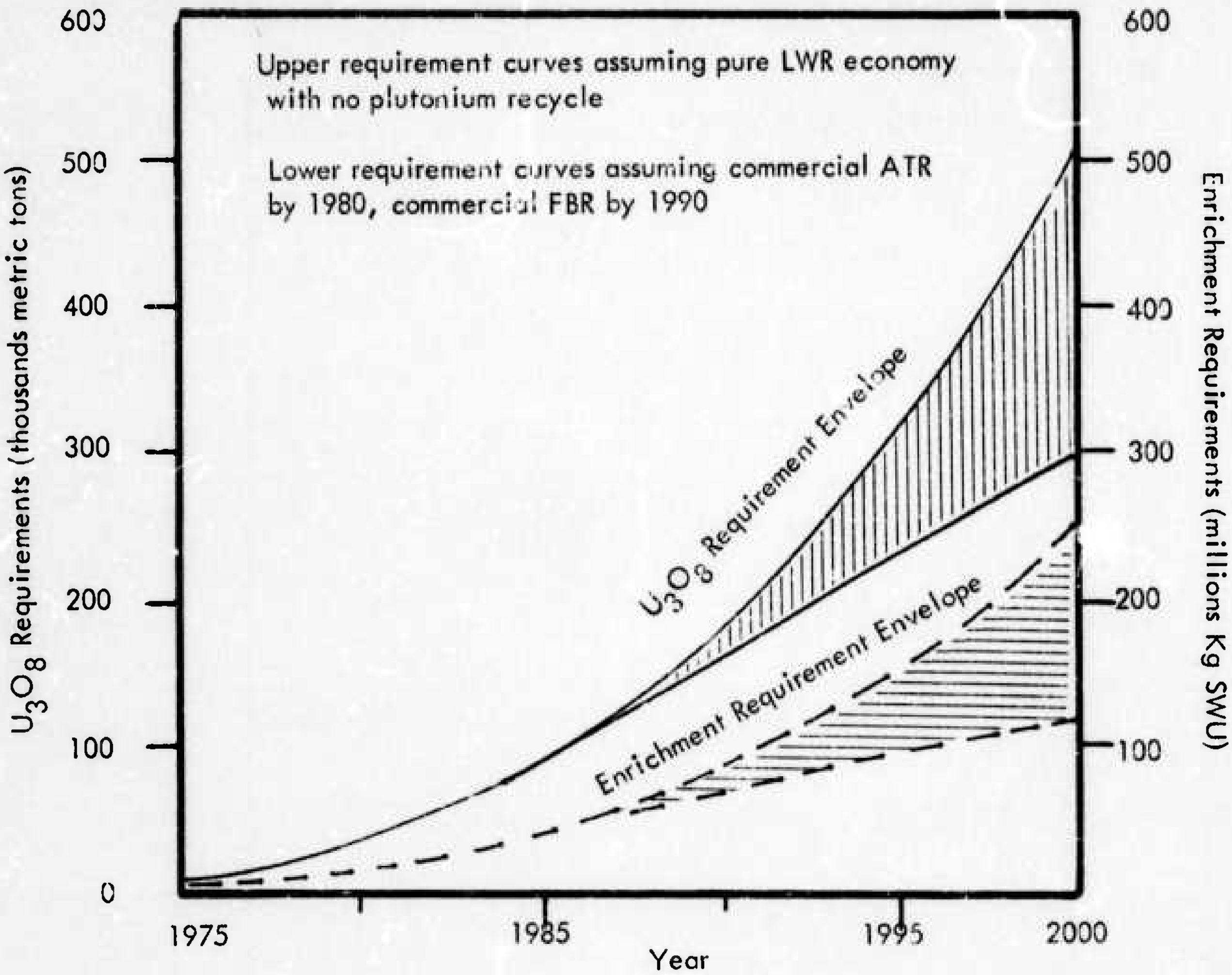

Figure E.5. Resource Requirements Envelope for Japan

for development of uranium resources in Niger. Basic surveys are also being carried out in Kenya and Somalia.

At present, Japan obtains all her nuclear fuel from the United States. If this sole source procurement relation were to continue, uranium resource requirements for Japan and the United States through 1985 would be as shown in Figure E.6. The uranium demands shown for the United States are taken from the latest official AEC forecast.[60] The Japanese uranium requirements shown are based on the estimates

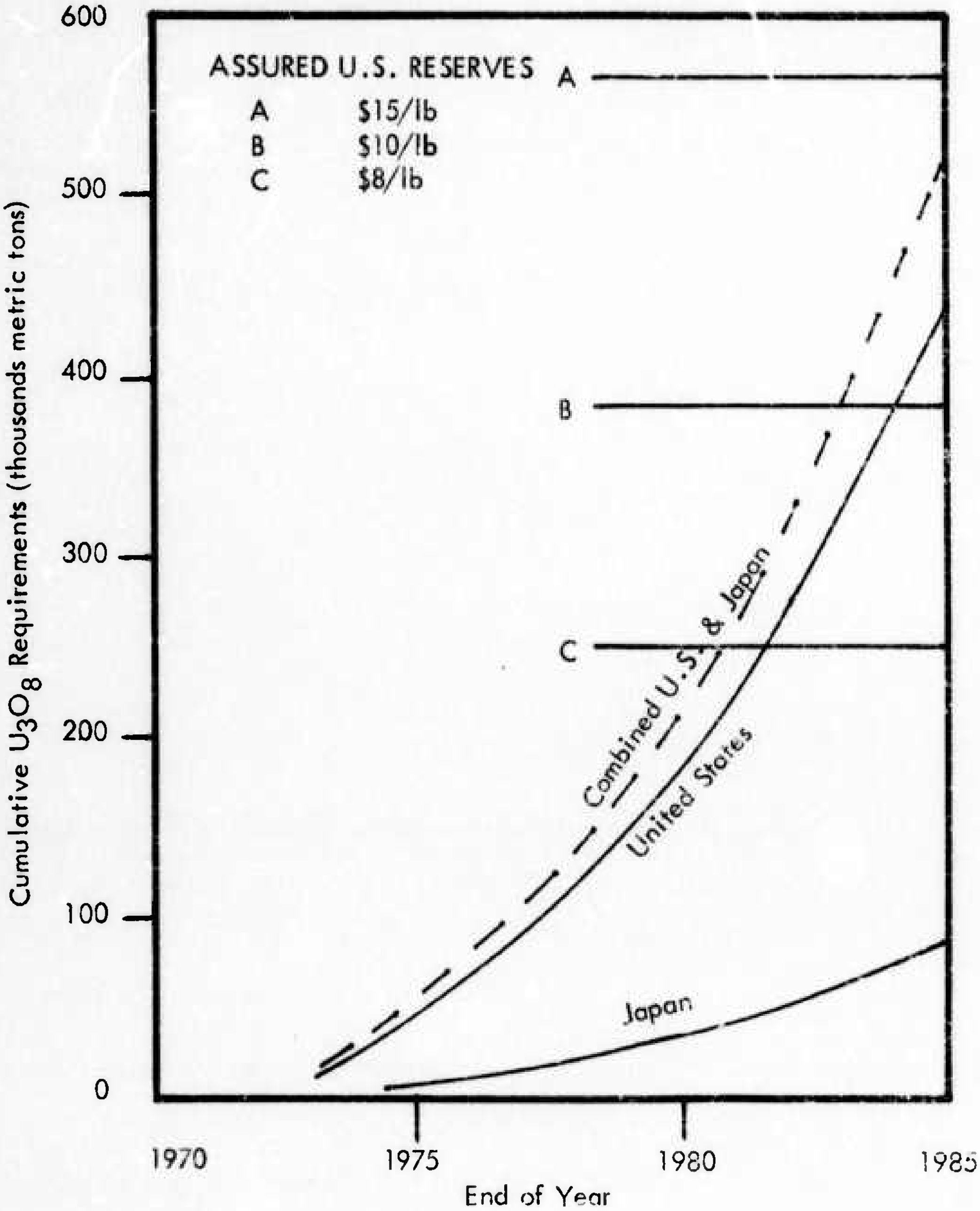

Figure E.6. Japanese and United States Uranium Requirements Compared with United States Resources made for a pure LWR nuclear industry. Also shown in Figure E.6 are the assured U.S. reserves for three different price levels. It is doubtful, of course, if Japan will continue to rely solely on the United States to supply her uranium fuel but as can be seen in Figure E.6, Japanese uranium requirements would not be of sufficient magnitude to seriously affect the supply of uranium for U.S. power needs. This is particularly true since, as was noted in describing the nuclear fuel cycle, power generation costs for nuclear reactors are not greatly affected by raw fuel costs. A doubling of the fuel cost from $8/lb to $16/lb would affect the total cost of nuclear-generated electricity by less than 10 percent. It should also be noted that the resource figures given in Figure E.6 are only for assured resources, the U.S. AEC presently estimates total proved plus potential U.S. uranium resources at $15 per pound or less at 1,146,000 metric tons. Based on past estimates, the present estimates are apt to be conservative.

Other assured uranium ore reserves in the world are given in Table E.4. Table E.4 gives assured reserves estimated to be recoverable under $8/lb. The figures given are apt to be quite conservative, and could be expected to more than double if costs to $15/lb are considered acceptable to Japan. The total western world uranium ore requirements through 1985 are expected to be about twice the United States uranium ore requirements, i.e., by 1985 the entire Western world cumulative demand for uranium should be on the order of 900,000 metric tons. This is well within the estimated world supply of low cost uranium. Thus, it appears that through 1985 Japan should have no problem meeting her uranium ore requirements. It is also likely that Japan's increasing efforts to secure other uranium suppliers than the United States will lessen Japan's dependence on the U.S. for uranium ore.

Table E.4. Potential Western Sources of Uranium Ore for Japanese Requirements

Country	Assured Uranium Reserves under $8/lb (Metric Tons U_3O_8)
United States	250,000
Australia	130,000
Canada	230,000
South Africa	205,000

E.2.4 Enrichment Sources

Japan is presently entirely dependent upon the United States for enrichment services, and has recently contracted with the U.S. for 10×10^6 Kg SWU worth of enrichment services worth $320 million. This amount, however, will not be adequate to meet Japan's needs through the remainder of the 1970s and additional enrichment capabilities will be needed by Japan before 1980. The planned cumulative separative work production by the U.S. AEC is shown in Figure E.7. The production curve takes into account the planned U.S. enrichment expansion program, namely the Cascade Improvement Program and Cascade Uprating Program, to expand the total U.S. enrichment capacity from 17,230,000 Kg SWU/year to 27,900,000 Kg SWU/year. Also shown in Figure E.7 is the Japanese projected enrichment requirements and the combined worldwide enrichment requirement. It is obvious from Figure E.7 that present U.S. enrichment facilities will not be adequate to meet worldwide demand through 1985.

The United States is aware that additional enrichment facilities will be needed in the early 1980s, and is presently negotiating with private industry to allow private industry to build future gas diffusion

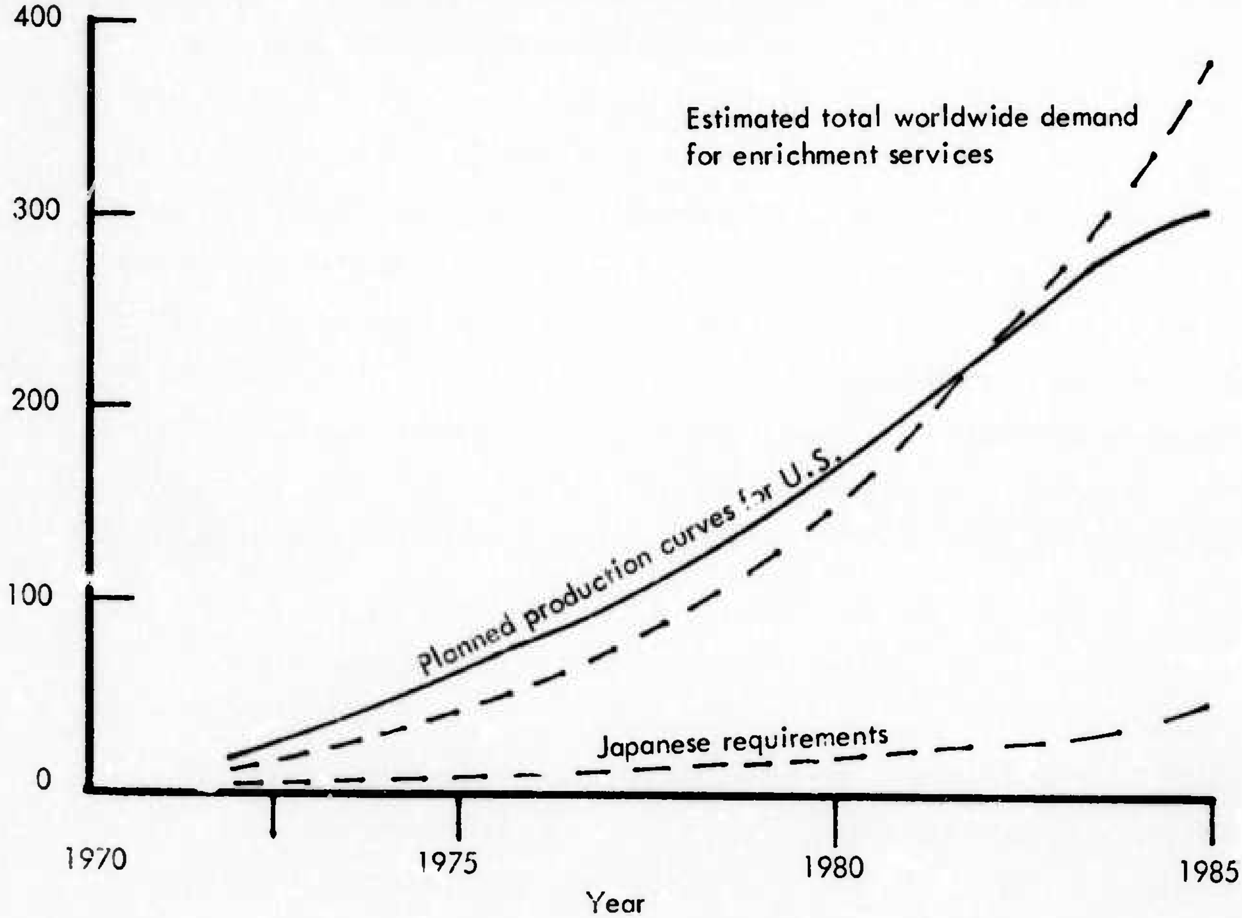

Figure E.7. Cumulative Separative Work Requirements

enrichment plants. The U.S. is also negotiating with other countries, notably Japan, on conditions under which there might be multinational cooperation in future plants which would use U.S. technologies for enrichment of uranium fuel material by gaseous diffusion. However, judging from the latest report by the Japanese Council on Uranium Enrichment Technology Development, the Japanese are not optimistic about receiving adequate information to permit them to develop a gas diffusion enrichment capability. Japan is bound to make all such information open to the public under the Atomic Power Basic Law, and does not feel that the U.S. will provide adequate information since almost all such information is presently classified.

Japan may meet its enrichment needs between now and 1985 by making additional purchases from the United States. Purchases of 30×10^6 Kg SWU of enrichment, which would have met most of Japan's need to 1985 were discussed with the U.S., but purchasing agreements broke down when the U.S. AEC published a new policy requiring a down payment and an obligation to place firm orders well in advance of actual delivery of the enriched fuel. The new policies are meant to provide a firm commitment for enrichment which will allow private industries the financial base on which to build additional enrichment facilities for the U.S. However, as a result of the new policies, additional enrichment purchases by Japan from the U.S. are, temporarily at least, stalled.

Japan has an agreement with Great Britain for possible enrichment services, and is negotiating a similar agreement with France. However, to date only the United States has provided enrichment services on a large-scale, commercial basis to other nations* and the ability of Britain and France to meet Japan's needs are unknown. Additionally, Japan has agreements with a number of countries, most notably Australia, for possible multinational enrichment ventures.

The Japanese Atomic Energy Agency has for some time been studying the possibility of domestically manufacturing enriched uranium. The Council on Uranium Enrichment Technology Development created by the Japanese AEC to study the problem has tentatively concluded that:

1. Japan can establish, as a national project, enrichment plants by 1985.

2. Top priority should be placed on the centrifugal separation process as opposed to the gas diffusion separation process.

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* Very recently, France and the USSR indicated a willingness to provide enrichment services on a commercial basis, but the details on their capabilities in this area are not yet known.

3. Gas diffusion enrichment is inadvisable for domestic plants. Japan should consider using the gas diffusion process only in international joint ventures and in foreign countries.

Most work done to date on development of the centrifuge enrichment process has been done by Great Britain, Germany and the Netherlands. A pilot centrifuge enrichment plant is now in operation, but performance data have not been published. The United States has done little work on the centrifuge enrichment process.

E.3 Ultimate Demand and Supply through 2000

As shown in Figure E.5, Japan's resource requirements beyond 1985 are very dependent upon the type of reactor system and fuel cycle which is used. Total resource requirements for the worst case in which no country develops a commercial breeder reactor before year 2000 are indicated in Figure E.8 against estimated total world reserves. As can be seen from Figure E.8, it is not likely that by year 2000 that there will be a shortage of reasonably priced uranium, even if advanced reactor types are not commercially developed by that year. Further, it is very likely that Japan will have developed a breeder reactor by year 2000 or before. With commercial development of a breeder reactor, uranium ore requirements will be greatly reduced.

If Japan develops breeder reactors, it should be noted that Japan's domestic reserves will become economically practical, and in a pure breeder economy Japan's present known resources of 7,700 tons of U_3O_8 would be adequate to generate 5.5×10^6 MW years of electrical power. This energy would be sufficient to provide for Japan's total electrical demand for about 20 years at the demand level expected in year 2000. Thus, while Japan's domestic resources is not significant in a LWR reconomy, it may provide an appreciable emergency supply in a breeder reactor economy.

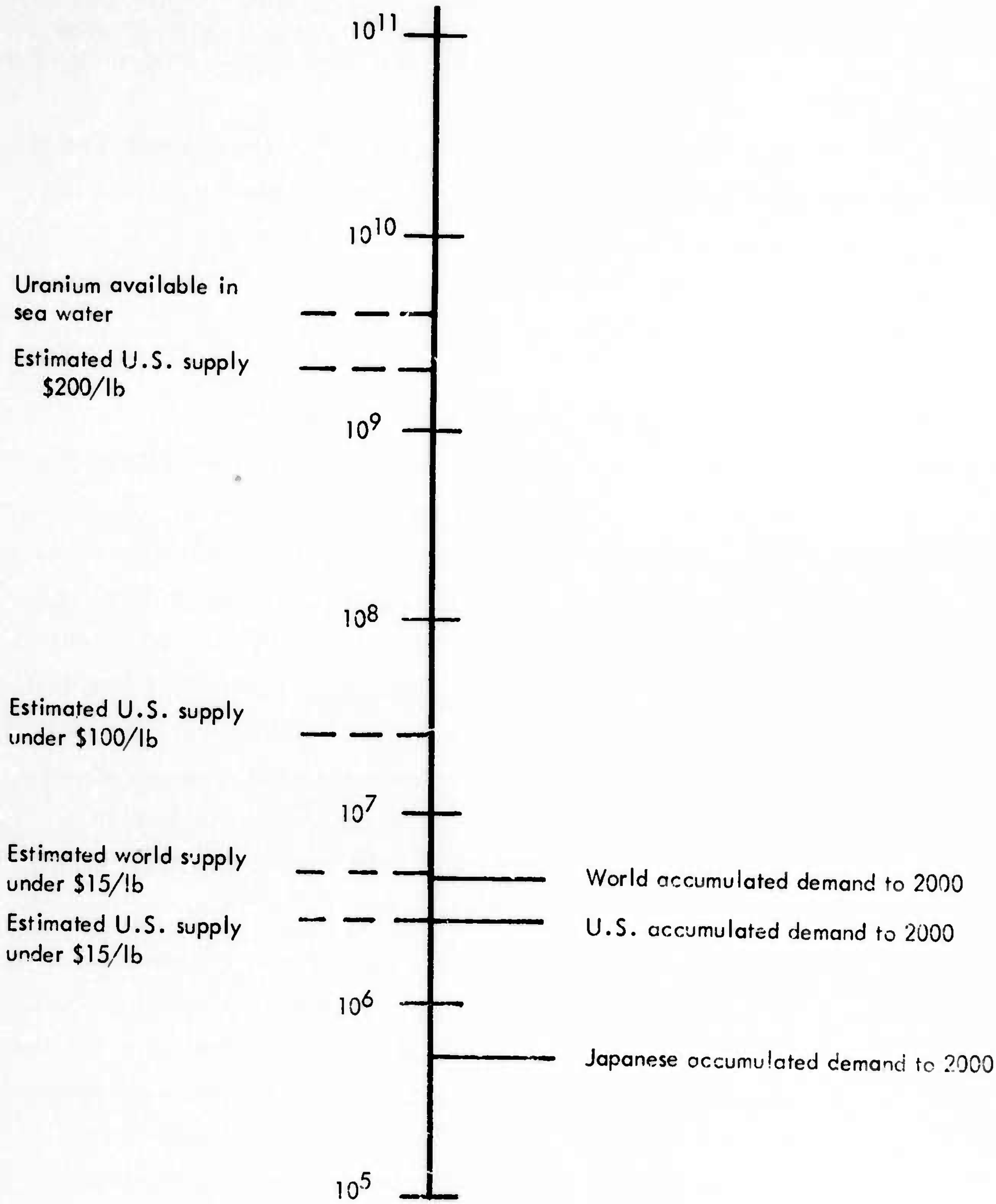

Figure E.8. World Requirements assuming No Commercial Use of Advanced Reactor Requirements before 2000

A possible domestic source of uranium for Japan is sea water. As shown in Figure E.8, there is a tremendous resource of uranium in sea water. The British carried out research on extracting uranium from sea water in the 1960s and estimated recovery costs from $11 to $100 per pound.[61] At present, uranium resources are such that recovery of uranium from sea water is not economical even at the lower price, but for breeder reactors uranium even at a cost of $100 per pound would be economically feasible. Thus, sea water may in fact, prove to be a practical source of uranium for Japan. Such a source would mean that Japan would no longer be dependent upon others for its uranium supply. Japan is in fact conducting much research in methods of extracting uranium from sea water and may well develop practical methods by the turn of the century.

Japan's requirements for enrichment services beyond 1985 may prove to be a more serious problem than her requirements for uranium ore. If Japan fails to develop the centrifuge process by 1985 or 1990, and is still dependent primarily upon LWRs, she may require substantial help from the United States, either in the form of enrichment sales or transfer of technology to allow her to develop a joint diffussion enrichment plant. However, it is more likely that Japan will be able to develop either advanced reactor types or enrichment facilities before year 2000, in which case obtaining enriched uranium ore is not expected to be a great problem.

E.4 Other Potential Uses of Nuclear Energy

So far nuclear energy has been projected to be used only in the manufacture of electricity. With such a restriction nuclear energy, even though it will generate most electrical power by year 2000, will not be the dominant energy source in Japan. However, the Japanese are actively pursuing the use of heat from nuclear reactors for use directly in industrial processes. At present, steam available from present LWRs for industrial processes is available only up to about 200-250°C (400-500°F). At this temperature, uses for the steam are fairly limited. If 400°C temperatures can be achieved, desulfurization of fuels and evaporation of crude petroleum can be achieved. At a temperature of 800°C, hydrogen can be produced and used elsewhere for almost all processes. At a temperature of 1000°C, coal can be gasified and iron ore reduced directly. The most feasible way to develop these high temperatures would appear to be through the development of the high temperature gas reactor (HTGR).

HTGRs are presently being built in the United States by Gulf General Atomic. These reactors would have to be developed somewhat more if they were to be used as the sole energy source in an iron and steel manufacturing process, but research at the Japan Atomic Energy Research Institute (JAERI) has led the Japanese to believe that 1000°C temperatures can be achieved by the use of HTGRs. Research on the use of nuclear power for iron making is also being done in West Germany, Great Britain, and other European communities.

The Nakamura Research Institute, the Iron and Steel Institute, and the Institute of Energy Economics have made a joint study of nuclear iron making for the Japanese. The conclusion was that nuclear iron making might be economically as well as technically feasible.

The Japanese at present are not developing as a national project an HTGR. However, it is feasible, but not probable, that by 1985 they will have developed the capability to use HTGRs directly in iron making and possibly other industrial uses. Technology-transfer from the United States which is presently building HTGRs for production of electricity, might well speed development of nuclear iron making in Japan.

The possible potential offered by the use of nuclear energy directly in industrial processes is shown in Figure E. 9, which shows the present and projected energy uses in Japan. As can be seen from Figure E. 9, some 50 percent of Japan's energy requirements presently go directly to industrial processes. For purposes of illustration, therefore, assume that by 1985 Japan has developed a practical nuclear reactor whose heat can be used directly in steel and chemical industries, and further assume that by 2000 50 percent of all of Japan's industrial energy needs are supplied by direct nuclear energy. If these projections were met, Japan's total nuclear energy production would change from that shown in Figure E. 4 to that shown in Figure E. 10.

The projections shown in Figure E. 10 are not meant to represent the most probable case, but are meant to give an upper bound for the use of nuclear energy in Japan. As can be seen from Figure E. 10, nuclear energy is not apt to have much effect on Japan's total energy supply through 1985, but by year 2000 nuclear energy could conceivably greatly reduce Japan's need for other energy supplies (primarily oil). Thus, the potential represented by the use of heat energy from nuclear reactors for steel and chemical industries is quite high, and in the 1970 Delphi Study, the Japanese Science and Technology Agency placed the development of nuclear heat energy for industrial uses just below the development of fusion reactors, breeder reactors and commercial enrichment plants in order of importance. Technology transfer from the United States in the field of HTGRs might greatly aid the Japanese in this field.

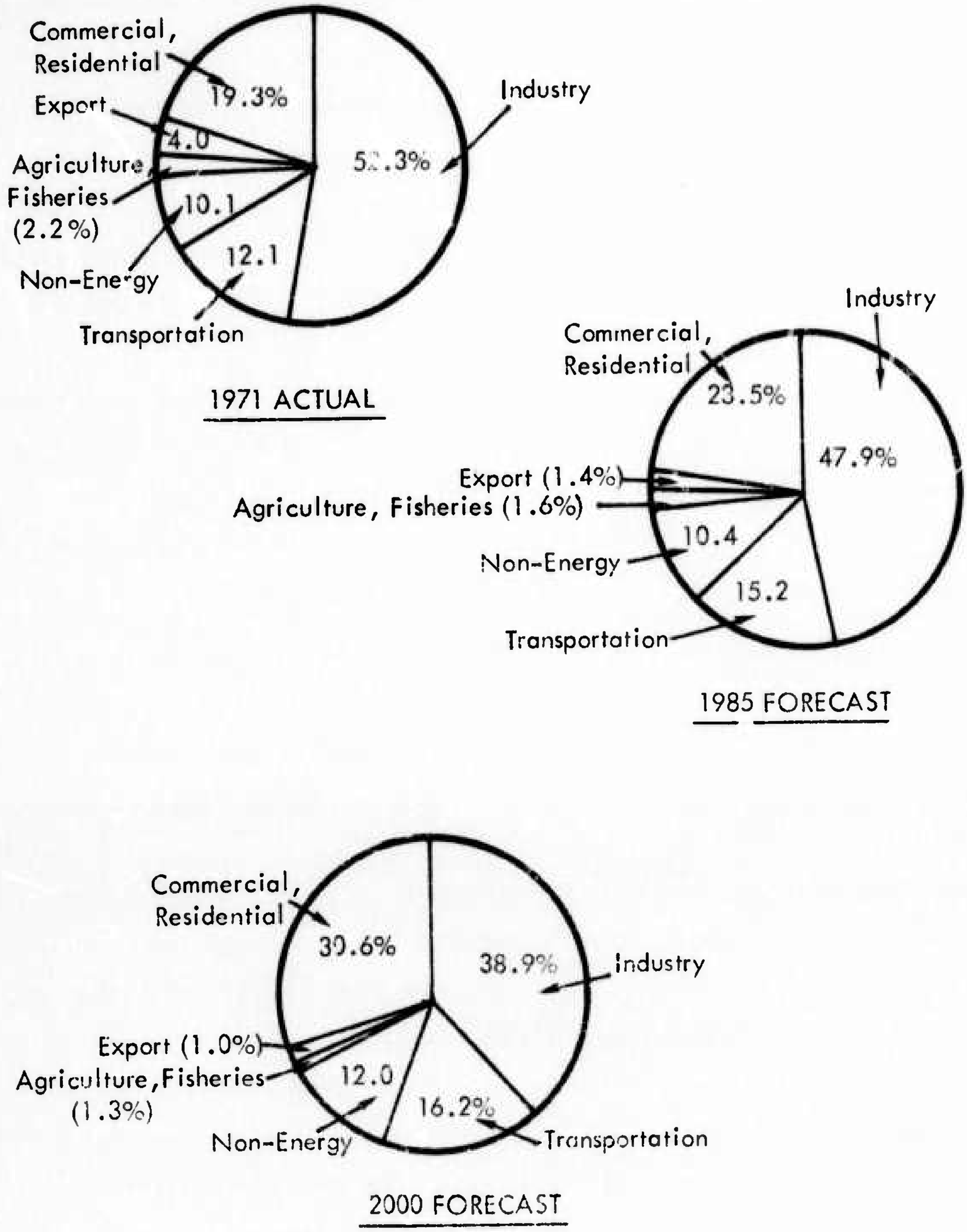

Figure E.9. Energy Consumption in Japan

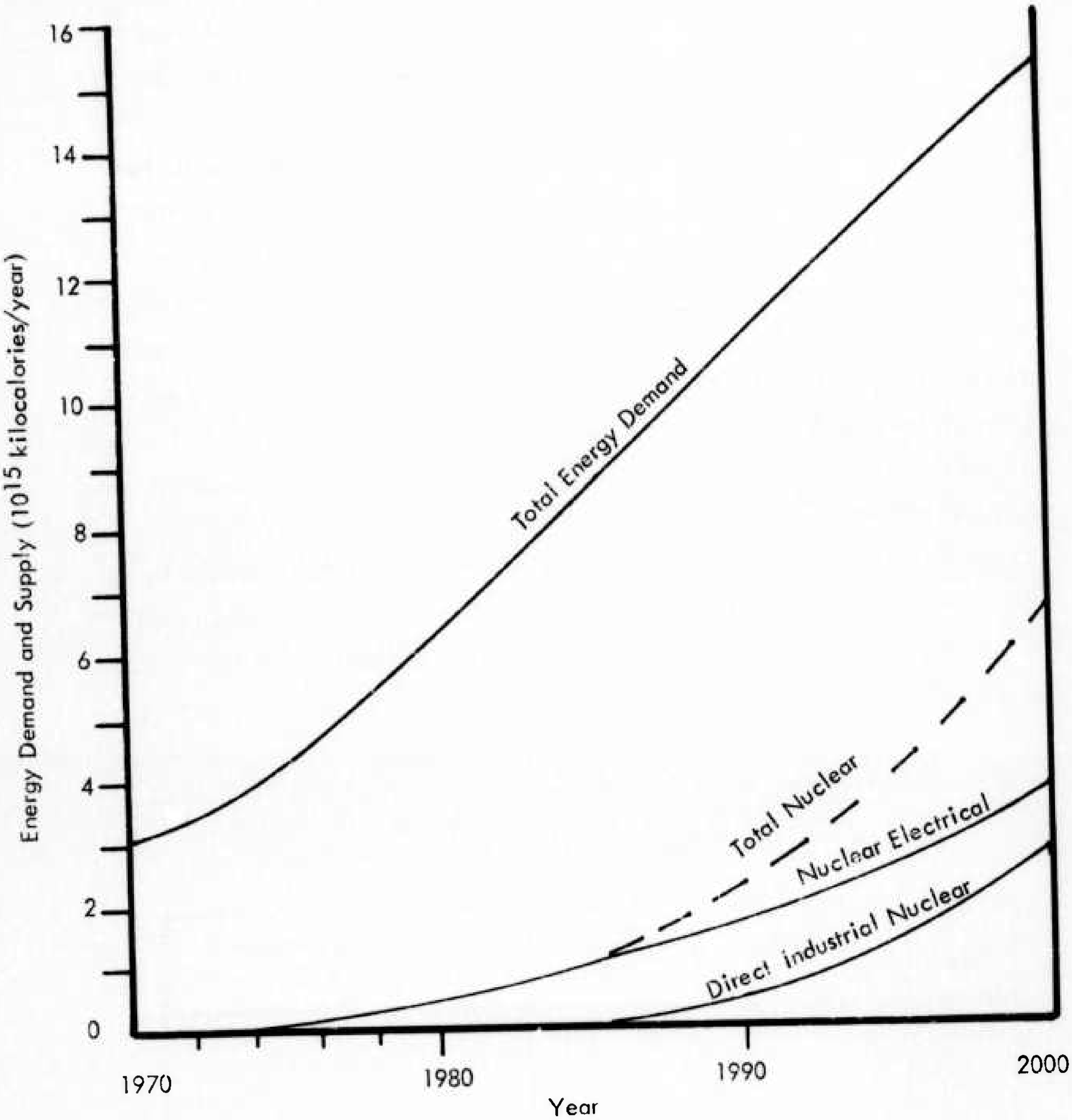

Figure E.10. Energy Production in Japan assuming Rapid Development of Industrial Use of Heat from Nuclear Power

If HTGRs are developed as heat sources for industrial uses as shown in Figure E. 10, the resource requirements given earlier will need to be changed. The maximum resource requirements can be found assuming the use of HTGRs implied in Figure E. 10, and assuming that all HTGRs used are of present design rather than gas cooled breeder reactors. (If gas cooled breeders were used, the additional resource requirements would be negligible.) The total resource requirements are given in Table E. 5, and represent maximum requirements expected. While the resource requirements for U_3O_8 increase by the order of 50 percent by year 2000 from the projections given without HTGRs in use, Japan's uranium ore requirements are still not of such a magnitude that uranium prices should be influenced greatly. The HTGRs will also require the use of thorium, but the requirements for thorium will be insignificant in comparison to known reserves. However, the figures do show, once again, that if Japan succeeds in rapidly expanding nuclear power without developing a breeder reactor before year 2000, that she

Table E.5. Maximum Resource Requirements assuming Use of Heat Energy from Reactors (HTGRs) for Industrial Resources as well as Use of LWRs for Electrical Power

Year	Cumulative Uranium Requirements (Metric Tons U_3O_8)	Cumulative Enrichment Requirements (10^6 Kg SWU)*
1975	8,000	4
1980	36,000	17
1985	92,000	45
1990	202,000	105
2000	726,000	419

Kg SWU = kilograms of Separative Work Units will have substantial enrichment requirements. If Japan further fails to develop her own enrichment facilities, she may be very dependent upon the U.S. for increasing enrichment services.

E.5 Special Problems

At present, Japan is able to construct a large commercial nuclear generation station with a lead time of five years. That is, from commitment to build to completion of building takes five years. In the United States the lead time is eight years or more. Much of the difference is due to the licensing difficulties experienced in the United States. Indications are that Japan is apt to experience slowdowns in construction in the future much as the United States is presently experiencing slowdowns. Any such difficulties will mean that the projections made by the Japanese to the year 1985 will not be met. The SAI base case projection assumes some slowdown in the growth of the Japanese nuclear industry in comparison to the present Japanese AEC projections.

The problems apt to face the Japanese nuclear industry will result from several factors, but the key factors can be considered in the context of four headings:

- Site selection
- Safety
- Radioactivity releases
- Waste disposal

Site selection problems in Japan are apt to become quite acute in Japan. To see this, note that by year 2000 Japan is projected to have an installed capacity of 210×10^3 MWe, the equivalent of 210-1000 MWe plants. If these plants were uniformly distributed throughout Japan, they would be on 28-mile centers, i.e., one plant every 28 miles. Already opposition by local populations to nuclear sites in their areas is becoming quite common, and the question of siting is apt to become increasingly difficult in years to come.

Of course, many of the siting problems involved with nuclear plants would exist for conventional thermal plants, but certain features such as heat release and radioactivity releases may make siting nuclear plants more difficult. LWR-type power plants in use today require larger amounts of cooling water and discharge greater amounts of waste heat to the water than comparatively sized fossil-fueled plants. Claims of damage to fisheries from thermal discharges in Japan are receiving wide publicity and limitations on thermal discharges are likely to occur. Such limitations have already occurred in the United States. However, experience in the United States has shown that cooling ponds or towers can be constructed, without delaying the entire nuclear power plant construction, which will greatly reduce cooling requirements. Such additions do add to the cost of nuclear plants, but not to an unsurmountable degree. It is quite possible that some future Japanese nuclear plants will be constructed with cooling towers or ponds. Another possible solution would be to float large power plants on special barges in the ocean, a concept being developed in the United States. Such a concept, if it proves feasible might be very appropriate to an island nation such as Japan.

Radioactive releases from nuclear plants are generally of quite low levels, but in areas of high population, concentrations may still result in relatively high integrated whole population doses. Public pressures against radioactive releases may force nuclear reactors in Japan to be located in relatively remote sites, which are relatively scarce in Japan.

The consequences of serious accidents associated with nuclear reactors, such as those postulated to occur in a loss of coolant accident, can be much more severe than any conceivable accident at a conventional thermal plant. Thus, even though nuclear accident probabilities may be very low, nuclear reactors often raise serious safety concerns in the public. Such concerns are being increasingly voiced in Japan, and are being used by minority political parties in Japan as political issues. The Japan Atomic Industrial Forum reports some success by minority parties to use the nuclear safety issue to influence the elections in areas of nuclear plant sites. Given the vague fears latent in the Japanese people about radiation, it is not inconceivable that a moratorium might be forced on the nuclear industry which would essentially shutdown all nuclear construction for an appreciable length of time.

Radioactive releases from nuclear reactors are typically only a small fraction of natural background radiation, but since there appears to be no "threshold" for radiation (i. e., no lower limited below which there are no effects) even small amounts of radiation can be statistically assumed to cause some effect. At present Japan uses the limits for radioactive releases set by the International Committee on Radiation Protection (ICRP), i. e., radiation not to exceed 500 millirem/year to a member of the general population. Arguments that this is too high are being pushed by groups such as the Japan Scientists Association. If the limits are changed to the new limits being proposed in the United States (effectively 5 millirem/year), additional costs and some delays will be encountered by Japan in building nuclear reactors.

Disposal of radioactive wastes from nuclear reactors is one which Japan will have to pay increasing attention as nuclear reactors become more prevalent. To date Japan has done little work on developing means for radioactive waste disposal. Dumping wastes at sea will most likely be banned by international agreement in the fugure. Japan may be somewhat limited in its options in comparison to the United States which has several natural areas which have been proposed for dumping of radioactive wastes, but the volume of high level wastes from nuclear reactors is quite small and Japan may well be able to use methods or areas developed in the United States.

In summary, the nuclear industry in Japan faces many safety and environmental issues which may slow its growth in future years below present forecasts. The nuclear industry in the United States has experienced a definite slowdown due to these safety and environmental concerns by parts of the populace. It is even conceivable that a complete shutdown of nuclear construction might occur in Japan as the result of political pressures or as a result of a serious reactor accident in Japan.

E.6 Nuclear Energy Generation, Fusion

Nuclear fusion represents a nearly ideal, abundant power source for a country such as Japan which has very limited conventional domestic energy sources. For this reason, Japan is conducting research in fusion areas. However, the Japanese do not expect actual commercial development of fusion power in this century and fusion power has not been considered in the energy projections made in this report.

Studies of fusion began in Japan in the Japanese universities in about 1957 and the Plasma Research Laboratory was formed in 1961 to do basic research in plasma areas. However, it was not until very recently that organized efforts have been started to specifically develop a fusion reactor. Present funding in Japan for fusion development is now at the level of a few million dollars compared with a proposed U.S.

1974 fiscal budget of $44 M. Large increases in spending in Japan for fusion research will probably not occur until the scientific feasibility of fusion has been demonstrated, and such a demonstration is apt to come from countries such as the U.S. or the USSR which have done considerably more research in the fusion field. A demonstration of scientific feasibility is not expected to be achieved in this country until around 1980. Even given a successful demonstration of scientific feasibility, many engineering problems will need to be solved before a practical fusion power plant can be built. Very little work on the engineering problems associated with maintaining a strong magnetic field produced by superconducting magnets in the vicinity of an intense neutron field and high heat loads has been done. The solution of the engineering problems associated with building a practical fusion reactor is apt to require large amounts of funding and many years of effort. A demonstration of the engineering practicality of fusion reactors is not expected in this country before 1990, and prototype fusion reactor construction is not planned in Japan before year 2000. It does not appear that even if scientific feasibility of fusion were demonstrated within 1973, that fusion reactors would be developed to a true commercial level before year 2000.

A possible exception which might lead to the development of practical fusion reactors before year 2000 is the laser ignition approach to fusion. It is possible that very high powered lasers could be used to heat deuterium-tritium fuel to high enough temperatures to produce significant fusion without a confining magnetic field. Such a development would reduce some of the engineering problems foreseen for the plasma fusion-type reactors, and might mean that relatively small-scale fusion reactors would be economical. If laser ignition net power production feasibility were to be demonstrated in the near future, fusion power might have a significant impact on world energy needs in all the advanced nations, such as Japan, before year 2000. The very great impact such a development could have on the need for oil reserves and supplies suggests that more information on the progress of laser ignition fusion is needed by energy planners planners in Japan as well as the United States. However, the key aspects of work on laser-ignited fusion research in this country are classified by the U.S. Atomic Energy Commission and an accurate assessment of progress in this area is difficult to make. There are no reports of significant research in laser-ignition fusion being conducted in Japan.

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